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ORIGINAL ARTICLES.

I.—On the Discovery of Silurian Fossils of Ludlow Age in Cornwall.

By Uffield Green, F.G.S.

THIS is merely a brief note to record the discovery of fossils of undoubted Silurian age in the "Black Slates with limestone lenticles" which occur on the shore and in the cliff at Fletching's Cove, near Porthalla, and at Porthluney, near Gorran, in Cornwall.

For many years the most careful search in these beds for fossils has been unsuccessful beyond minute ossicles of crinoids and indeterminable fragments of Orthocerata. I have spent many weeks each year hunting for fossils, often alone, but sometimes in the company of Dr. Barrois, Mr. Teall, Messrs. Vassell, Sherborn, Howard Fox, and others, and beyond finding the well-known Brachiopoda in the quartzites of Gorran and Carne, our search has seemed almost in vain. Some four years ago, however, Mr. Sherborn found in the Black Slates of Fletching's Cove an impression, which he identified as a fragment of *Serpulites longissimus*, J. de C. Sow., of Ludlow age. This fragment is now in the Museum of Practical Geology. This Spring, in company with Messrs. E. Dixon, of the Geological Survey, and Mr. G. T. Prior, of the British Museum, I paid my usual visit to Cornwall, and was rewarded by finding at Porthluney in these Black Slates a limestone lenticle which contained Orthocerata in quantity. It was only on the 6th June that I showed this to Mr. Sherborn, who at once took it to Mr. G. C. Crick, who recognised two of the fossils therein contained as comparable with *Actinoceras baccatum*, H. Woodw., and *Barrandeoceras holtianum* (Blake), together with other fragments also of Upper Silurian age. These two Cephalopods taken together with the *Serpulites* stamp the rock as of uppermost Silurian, probably Ludlow age. The specimen is in the British Museum (Nat. Hist.).

I think I may now venture to state that we have at last succeeded in establishing a definite fact in the geology of this part of Cornwall, thus fixing a base-line for the rocks intervening between it and the

Taunusian beds of Looe and Fowey. These rocks I propose to correlate with the Gedinnian of the Continent in a subsequent paper.

I may mention that at Looe I have at last found the most characteristic fossil of the Taunusian series, *Onychia* (*Kochia*) *capuliformis*, Sandberger, as well as *Spirifer mercurii* (Gosselet).

II.—An Eocene Outcrop in Central Africa.

By Captain P. S. Lelean, R.A.M.C., F.R.C.S. Eng.

(With a Map in the text.)

AT the heart of Africa lies a vast area, so remote, so inaccessible, and hence so little known, that for the explorer it possesses a fascination all its own. The interests of the geologist have perhaps received less recognition than those of his fellow-scientists from the pen of the traveller; and there must be much that he would wish to know lying hidden in these distant regions awaiting discovery and publication. There is thus an encouragement to make known any facts which may throw light upon the geological structure of those parts, however small the contribution may be.

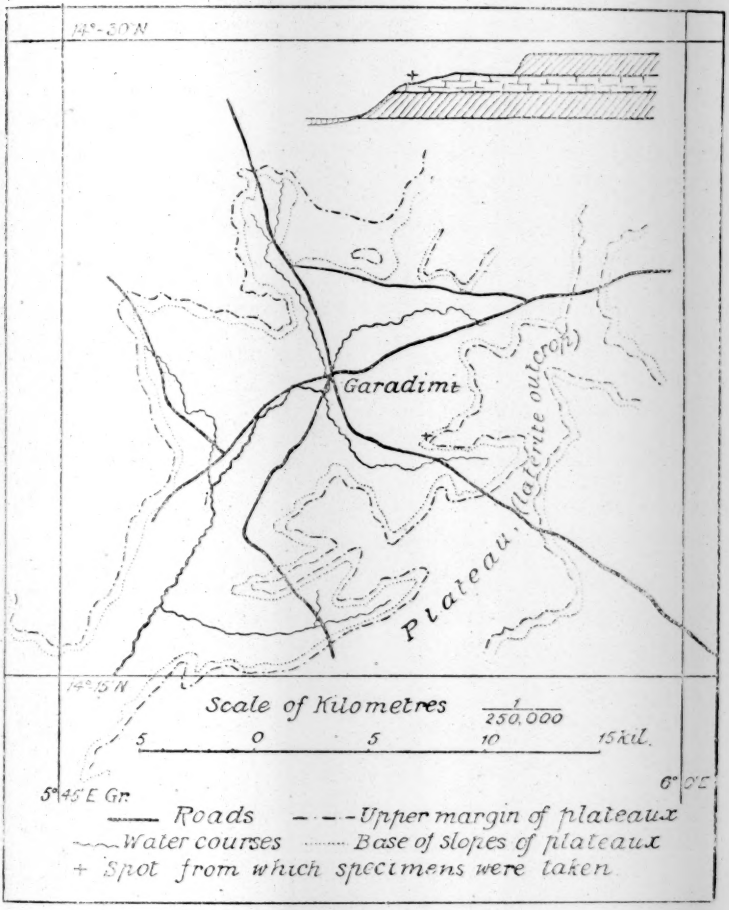
While serving recently with the Anglo-French Boundary Commission (Niger–Chad) we found an outcrop of a fossil-bearing stratum in the region of the Sokoto, having, as shown in the accompanying map, giving its latitude and longitude, a position near the verge of the Great Sahara Desert. On my return, the specimens secured were submitted to the palæontologists of the British Museum, one of whom, Dr. F. A. Bather, has kindly drawn up the description which follows in a separate paper. For me it only remains to give a few particulars of the general and localized formation to supplement his account.

Generally, the country consists of sandy plains, roughly estimated as lying some 500 or 600 feet above sea-level. These plains are traversed by watercourses, which contain running water only for some five or six weeks in the year, the rainfall of 535 mm. lasting during three months. A permanent water-supply is obtained by deep wells, which in some places reach a depth of 400 feet before tapping a constant source.

From the plains rise hills in isolated masses or in chains, with abrupt slopes, often almost precipitous, and with summits ending at from 300 to 400 feet in plateaux of remarkably uniform height, unbroken by further elevations. These hills consist mainly of laterite, marl, and limestone, but in places are found outcrops of syenitic granite; among minerals are some calcite, a little quartz, and considerable quantities of mica.

The accompanying map, kindly furnished by Capt. C. St. Foulkes, R.E., shows to the east of Garadimi a plateau with the characters described. Its steep sides are covered by boulders and detached rocks of all sizes, and the formation is of laterite throughout. From this plateau a long promontory reaches out towards Garadimi, falling abruptly for some distance to merge into a spur composed entirely

of fossil-bearing limestone, whence at the spot marked + were obtained remains of Mollusca, Echinoidea, and Foraminifera, which, according to the determinations by Dr. Bather and Mr. R. Bullen Newton, suggest a Middle Eocene age for the rock. This spur was evidently more resistant than the promontory; it was less than 200 feet thick, and between it and the general plain level below lay



another stratum of laterite, while the limestone itself was markedly stratified. Similar discoveries of fossils ascribed to the Middle Eocene period have been made by the French at Zinder, some 300 miles to the east of Garadimi, and have been commented on by Professor A. de Lapparent.

III.—Eocene Echinoids from Sokoto.

By F. A. Bather, M.A., D.Sc., British Museum (Natural History).

(PLATE XI.)

IT is fortunate that Captain Lelean not merely discovered these fossils at Garadimi in Sokoto, but that he had enough sense of their importance to spend some time and trouble in their collection, and that now he has generously presented them to the British Museum. The collection includes four echinoid tests, five natural casts of Mollusca, and a few rock-specimens containing *Operculina* and other Foraminifera. The Mollusca, so far as their state of preservation admits, have been determined by Mr. R. Bullen Newton as: 3 *Lucina* cf. *gigantea* Deshayes, 1 *Voluta* cf. *cithara* Lamarck, and 1 undetermined Gastropod. The Echinoidea were partly covered by an impure limestone closely adherent to the test. The portions not so covered were in many places considerably worn, and the calcite was split by cracks, probably due to alternations of temperature, and rendering it very difficult to follow the course of the sutures. The appearance of these and the other specimens shows clearly that they have been lying on the surface of the ground for some time, and, in fact, Captain Lelean informs me that they were not picked out of the solid rock, but from the talus at the foot of the cliff. The notable variations in the matrix of the different specimens are thus accounted for. None the less it will be seen in the sequel that all the specimens are consistent with the ascription of a Middle Eocene age to the mass of limestone from which they were derived. Of the four echinoids, two have been determined as belonging to the genus *Plesiolampas* and two to the genus *Hemiaster*. In each case there is a larger and better preserved specimen referred to as A, and a smaller one referred to as B.

[The MS. of this paper was sent in on March 14th, 1904. After the proof had been received, Captain Foulkes, R.E., kindly presented to the British Museum a further collection of fossils from this region. It included two more specimens of the *Plesiolampas*, referred to as C and D; and twelve more of the *Hemiaster*, lettered according to their decreasing size from C to O. The accompanying label reads: "In bed of indurated chalk running into grey limestone underlying laterite. Found near road just above Tamaské, where it descends from plateau." These specimens have confirmed the main conclusions already set down, while affording a wider basis for the diagnoses. Beyond this, a few allusions or illustrations are all that it has been possible to introduce at this more than eleventh hour.—June 9th, 1904.]

Plesiolampas Duncan & Sladen, 1882.

Pal. Ind., ser. xiv, vol. i, pt. 3, Foss. Ech. W. Sind, pp. 9, 54, pls. i, xiii–xv (non *Plesiolampas*, Pomel, 1883, "Genera des Ech.," p. 62).

The two specimens agree entirely with the diagnosis of this genus of Cassidulidæ (subfam. Echinolampadinæ) as drawn up in the above-quoted work, and as repeated in P. M. Duncan's "Revision of the Echinoidea" (J. Linn. Soc. Zool., xxiii, p. 193; 1889). They have not the crenulate and perforate tubercles of *Oriolampas* Munier-Chalmas. They differ, however, from the six species which Duncan & Sladen described from the Eocene of Sind, and I am

unable to find any other valid species of the genus. Pomel's Cassidulid genus of the same name would, if accepted, belong to the Echinanthinæ. *Conoclypeus rostratus* R. Tate, 1894, was referred by its author to *Plesiolampas* in 1898 (J.R. Soc. N.S. Wales, xxxi, p. 412), but Mr. J. Lambert in the same year showed that it was an *Echinolampas*, and named it *E. Tatei* (Rev. Crit. Paléozool., ii, p. 164). Even if *Palæopneustes conicus* Dames, 1877, could, as Duncan suggested, be referred to *Plesiolampas*, it could not possibly be related to the present species, which I therefore propose to describe as

Plesiolampas Saharæ, n.sp. (Pl. XI, Figs. 1–5.)

Diagnosis.—Outline oblong, rounded in front, slightly rostrate behind; margins tumid; dorsal surface in transverse profile slightly conoid; length 100,[1] width 87–91, height 51–53. Ambulacral areas raised; petals do not reach margin, posterior pair being most remote, their greatest width from 11 to 16, interporiferous area not quite twice width of poriferous; pores conjugate and sloping adactinally. Peristome deeply sunk, transversely elongate, eccentric in front. Periproct at extreme actinal margin. Ornament of tubercles sunk in scrobicules of thrice their diameter, irregularly scattered on dorsal surface, more regularly crowded actinally.

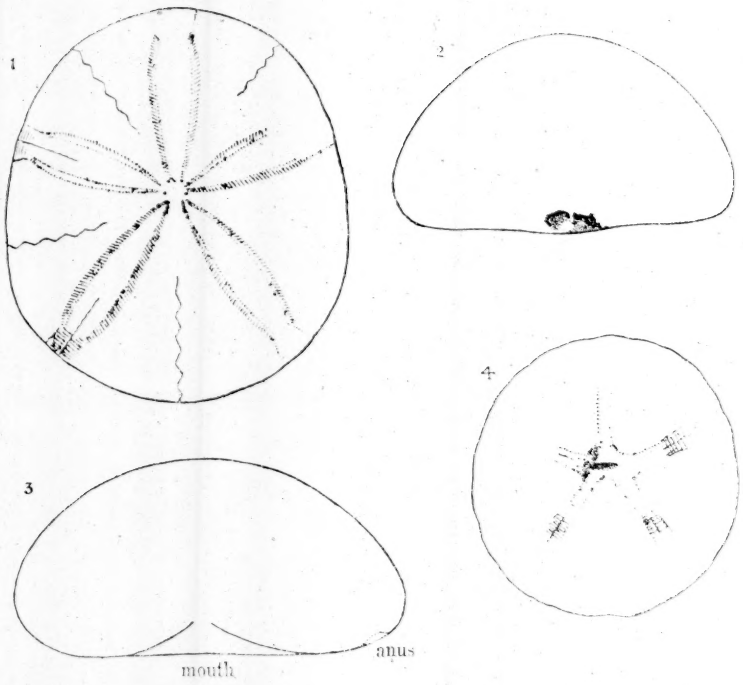
Description of specimen A (B.M. registered E 4824).—Test almost complete, rubbed on left side, fractured in other places. This is the holotype.

General Form.—Ambital outline approaches an oblong, with gentle curve in front, passing into wide curves on the sides, which are further apart posteriorly, then more tapering behind and very slightly truncate. Margin tumid, very slightly rostrate behind. Actinal surface deeply sunk round peristome, to fully 5 mm. below base-plane,[2] otherwise gently convex. Peristome slightly eccentric in front, circa 24 mm. from anterior vertical plane. Height of ambitus above base-plane, circa 10 mm. in front, circa 7 mm. behind. Total length, 52·3 mm. Greatest width, 45·6 mm. at circa 28 mm. from anterior vertical plane. Here also is the vertex, 27 mm. above base-plane. Dorsal surface slightly conoid in transverse profile; in longitudinal profile, slopes down with a sharper and more convex curve anteriorly than posteriorly. (See Text-figures 1–3, p. 294.)

Apical System.—Slightly anterior to vertex, its centre being circa 23 mm. from anterior vertical plane. The 4 gonopores are circular and about equal; posterior pores 1·9 mm. apart, anterior pores 1·25 mm. apart. Oculars and their pores minute and almost indistinguishable. As usual in the genus, the 4 genital plates are fused,

[1] In the diagnoses relative measurements are given in hundredths of the length; in the descriptions the actual measurements are given in millimetres. Here length = 56–60·5 mm. The radii and interradii are numbered on Loven's system.

[2] The base-plane is the flat horizontal surface on which the denuded test assumes stable equilibrium in its natural posture. The anterior vertical plane is at right angles to this and to the sagittal plane, and parallel to the transversal. The height of the vertex or any other part should always be measured from the base-plane.



Plesiolampas Saharæ.

Fig. 1.—Outline and petals of abactinal surface of A.

,, 2.—Outline of A from posterior end.

,, 3.—Outline of A from left side, showing position of peristome as though in section.

,, 4.—Actinal surface of B, roughly indicating peristome and incipient phyllodes.

All figures are natural size.

and all the space within the gonopores is filled with hydropores; the madreporite does not, however, extend backwards between the posterior oculars. (Pl. XI, Fig. 2.)

Ambulacra.— At the ambitus and on the tumid margin of the actinal surface the whole ambulacral area is slightly raised; within the petals the raising is almost confined to the interporiferous area, the poriferous areas being slightly depressed along their outer borders. The petals do not reach the ambitus, the posterior pair being the most remote from it. Angle included by rays II and IV, 135°; by rays I and V, 60°. The petals widen equably to near their ends, then close in slightly; the actual measurements are:—

	III.	II & IV.	I & V.
Length of petal ...	20·7 mm.	20·0–21·6 mm.	24·0–25·0 mm.
Greatest width ...	6·9 mm.	8·0– 7·5 mm.	8·4– 8·0 mm.
Width at distal end	5·0 mm.	4·3 mm.	5·3 mm.

Structure of petals:—In all lateral petals the posterior poriferous area curves more than the anterior (Pl. XI, Figs. 4 and 5). In ray IV, at the widest part of the petal, the width of the interporiferous area is 3·8 mm., while that of the poriferous area is 2·1 mm.; the widths of both diminish slightly towards the apex and more slightly towards their distal ends. The inner pores of an area are almost circular, the outer pores pyriform on the surface but becoming more circular deeper down, as is seen when the surface has been worn. This appearance is connected with the distinct conjugation of the pores. In the interporiferous area the sutures between the ambulacrals are almost at right angles to the perradius, with a tendency to slope adactinally from it. In the poriferous areas the adactinal slope of the suture is conspicuous, the angle contained by the two regions of the suture being 150°. Number of pore-pairs in petals: III, circa 48; II and IV, circa 51; I and V, circa 60. But there are a few slight irregularities: thus, in the anterior poriferous area of ray IV, reckoning from the distal end of the petal, the outer pores are missing from sutures 1, 3, 4, 6, 7, 8, the inner pores remaining normal, except 3 and 4, which are diminished; outer pore 5 is larger than usual (Pl. XI, Fig. 4). Occasional atrophy or suppression of a pore occurs in the other rays.

From the contracted ends of the petals the ambulacra widen again towards the ambitus, and then lessen in width towards the peristome, widening slightly just before they reach it. The series of double pores of the petals changes very rapidly, if not quite abruptly, into a series of minute single pores which appears to continue the inner row of the double pores. It passes over the ambitus on to the actinal surface of the test; as it approaches the peristome the pores increase in size, and at the oral end of the ambulacrum appear to be some half-dozen supplementary pores on each side, forming a rudimentary phyllode. This is more clearly seen in B (Text-fig. 4). but the structure in A seems to have been similar.

Interradials.— In the upper part of the abactinal surface, the sutures between these plates are straight; in the lower part the sutures have a downward bend in the middle. The number of

ambulacrals abutting on a single interambulacral is about 7 half-way down a petal, fewer nearer the apex, and more at the distal end. The arrangement of the interradials on the actinal surface cannot be distinguished.

Peristome.—Not fully exposed, but enough matrix has been worked away to show that it is about 1·5 mm. in front of the middle line, transversely elongate, narrow antero-posteriorly, and deeply sunken.

Periproct.—At extreme margin of actinal surface, invisible from above; longitudinally elongate, oval or subpyriform; circa 7·7 × 4·2 mm.

Ornament.—Small primary tubercles, varying slightly in thickness, non-crenulate, imperforate, sunk in a scrobicule of thrice their diameter, to such a depth that their summits are flush with the general surface; irregularly disposed on abactinal surface, both on interambulacral and interporiferous areas, at distances varying from about half the width to twice the width of the scrobicule; more regularly disposed in rows on actinal surface, very slightly wider, and crowded so that the space between them equals about one-third the width of the scrobicule. Miliary granules, crowded and often confluent, fill all spaces between the scrobicules, and tend to form a slightly defined scrobicular circle; they cover the ridges dividing the conjugate podial pores; between periproct and peristome they are larger, and seem here to cover a median tract from which tubercles are almost, if not wholly, absent. (Cf. Pl. XI, Figs. 1 and 3.)

Specimen B (B.M. regd. E 4825).—Much smaller than A, but of the same general shape: length 36·8 mm., width 35 mm., height 17·5 mm. The length and height, however, have been much reduced by erosion of the test, which has also caused the excavation around the peristome to appear relatively less than in A, while the periproct can scarcely be distinguished.

[Specimens C & D (B.M. regd. E 4833 and E 4834).—From Tamaské. C, which is fairly well preserved, has length 60·5 mm., width 55 mm., height 32 mm. This indicates a slight increase in relative width and height with age. Otherwise C agrees closely with A. Its measurements are taken into account in the diagnosis. D is a mere fragment, but shows the ornament so much more clearly than the other specimens that it has been selected for figuring (Pl. XI, Figs. 1, 3). On the actinal surface, the tubercles are in places more crowded than shown in the figure.]

Relations to other species.—Generally speaking, *Plesiolampas Saharæ* is stouter, wider, more tumid at the margin, and more loftily domed than any of the Indian species described by Duncan & Sladen. Thus, *P. elongata* is much narrower and flatter; *P. prælonga* is much more elongate, more rostrate, and has narrower poriferous areas in the petals; *P. ovalis* is also more rostrate, and has relatively shorter and narrower petals; in *P. rostrata*, which has wide petals, scarcely convergent distally, the periproct is more elongate and removed from the margin, while the low test slopes gently from the vertex to the margin and has a slight posterior ridge; the outline of *P. polygonalis*, though somewhat reminiscent of *P. Saharæ*, is nearer a pentagon, and is wider in front instead of behind, the low upper

surface is gently domed, the petals narrow and very slightly convergent; *P. placenta* is the nearest to our species and particularly resembles B, but, as compared with the unworn A, it is much thinner and flatter, while its ornament is said to be larger and scantier on the actinal surface, the reverse of *P. Saharæ*.

Evidence as to age.—All species of this genus previously described are found in Sind. *P. elongata* comes from the Strata below the Trap, which appear to be at the base of the Tertiary. The other species, some of which are more like *P. Saharæ*, come from the top of the Ranikot Series, which is thought to be Lower Eocene. There are in *P. Saharæ* no signs of more advanced evolution such as might suggest for it a later date.

Hemiaster Desor, 1847.

Ann. Sci. Nat. (3), viii, p. 16.
Syn. *Trachyaster* Pomel, 1883, Genera des Ech., p. 38.

There has been much discussion and uncertainty about the limits of this genus, and a summary of the position in the year 1889 is given by Duncan (Revision of Echinoidea, p. 225). However the genus be dismembered, it should retain as genotype the species described by A. Brongniart (1822) as *Spatangus bufo*, which was the first in Desor's list, and was subsequently referred to by him as characteristic of the genus. For present purposes it is unnecessary to consider whether or not *Abatus*, *Tripylus*, *Ditremaster*, and many other forms at one time or another placed with *Hemiaster*, should be left in the genus. The only one with which the specimens before us have anything to do is *Trachyaster*. In the genotype and other characteristic species of *Hemiaster*, the apical system is compact and ethmophract (the madreporite bounded posteriorly by genitals 1 and 4), and the compact nature of the system was recognised in Desor's revised diagnosis (Synopsis, 1858, p. 367). In certain species that would otherwise fall into *Hemiaster*, the apical system is ethmolysian (the madreporite extending backwards between genitals 1 and 4 and oculars I and V). For such species the genus *Trachyaster*, proposed by Pomel, was adopted by Cotteau (1887, Paléont. franç., Terrains Tert., Échinides Éocènes, p. 400). Duncan and Sladen (Ann. Mag. Nat. Hist. [6], ii, p. 329; 1888) rejected this genus for reasons partly bibliographic, partly morphological. Their objections of the former class were, however, based on an incomplete acquaintance with Pomel's writings, many of which were not accessible in this country till the death of their author. They stated, in fact, that the genus had been proposed without any genotype; and it is true that in the section of his work first published (1883) Pomel merely said "Le type est fossile du miocène supérieur." But from the 2e Livraison, p. 108 (1888), it is clear that the species intended was *Trachyaster globulus* Pomel, which was figured as *T. globosus* in the plates, first issued in 1887. There can therefore be no technical objection to the acceptance of Pomel's name. If there were, one would merely fall back on Cotteau's diagnosis and the genotype *T. Heberti* Cott. But Duncan & Sladen

further maintained that, as had already been shown by Mr. V. Gauthier, the ethmolysian apical system was merely a stage of development, connected by imperceptible gradations with the ethmophract stage, and that an individual might be ethmophract in youth and ethmolysian in old age. An objection of this nature could be brought against almost any character, except the few which may have arisen *per saltum*. When, however, a slowly evolving character affords the only distinction, and when the intermediate stages are many, as in the present case, it certainly does not seem advisable to base a generic division upon it alone. As a provisional subgeneric denomination for ethmolysian Hemiasters with four gonopores, the name *Trachyaster* has its conveniences. In such a sense, then, we may say that the specimens from Garadimi belong to *Trachyaster*.

Now according to the usual diagnoses, the only distinction between *Trachyaster* and *Linthia* (Desor, 1853, genotype *L. insignis* Merian) is that *Linthia* has a lateral fasciole passing beneath the periproct. The fact that in the majority of fossils it is very hard to distinguish this lateral fasciole is no argument against its taxonomic importance. But the researches of Mr. Alexander Agassiz seem to show that a lateral fasciole is the remains of what was once a single fasciole enclosing both petals and periproct, the latter structure being nearer the apex in early stages. As the periproct passes downwards from the apex, we may suppose that it carries the posterior region of this primitive fasciole downwards with it; and then that the peripetalous fasciole is recompleted above the periproct by a secondary posterior half. Whatever may be the function of the fasciole, it is reasonable to suppose that it is interfered with by this transportation; hence the appearance of a new fasciole in its place. Therefore one might anticipate for the lateral fasciole an early disappearance; and that there is actually such a tendency seems to be indicated by the frequent tenuity of the lateral fasciole and by the suppression of portions of it, producing the 'diffuse' state recognised in many well-preserved specimens. The lateral fasciole may therefore be regarded as a degenerate and disappearing structure, and as such it seems an unsafe character on which alone to base a distinction between two forms so extraordinarily alike as *Trachyaster* and *Linthia*. This was the opinion of Duncan (1889).

Fortunately there is another character, far more fundamental and far more constant, and this lies in the heteronomy of interradius 1 on the actinal surface, as described by Lovén (Études sur les Echinoidées, pp. 50, 51; 1875), and as first introduced into the formal diagnoses by Duncan (1889). According to these two authorities, the heteronomy in *Hemiaster* is of normal type, that in *Linthia* of ancient type. It is greatly to be regretted that so little attention has been paid to this feature by palæontologists, and that it is impossible to judge from either descriptions or drawings how far the normal and ancient heteronomies coincide with the absence and presence respectively of a lateral fasciole. Specimens of *Hemiaster bufo* in the British Museum (registered 34662) from

the type-locality, Havre, show normal heteronomy. It is desirable that the genotype of *Linthia* also should be examined on this point. Till that has been done, we must be content to follow the diagnoses of Duncan in this respect also.

On the preceding interpretation of the genera, the specimens from Garadimi belong to *Hemiaster*. While the peripetalous fasciole of A is visible quite clearly in places, the most minute and prolonged scrutiny has failed to reveal any trace of a lateral fasciole. Considering, however, that its absence might just conceivably be due to the weathering of the specimens, I investigated the structure of the actinal surface, with the result that in B there was traced normal heteronomy of interradius **1**. Among the Tamaské specimens, several show the lateral fasciole passing beneath the periproct, and would therefore be referred to *Linthia* by most palæontologists. But they all have distinct normal heteronomy (Pl. XI, Fig. 12). Therefore I place them in *Hemiaster*. At the same time I have thought it advisable, for the reasons given above, to compare them with species of *Linthia* as well as of *Hemiaster* (*Trachyaster*). Finding nothing under either name with which they could be placed, I venture to refer them to

Hemiaster sudanensis, n.sp. (Pl. XI, Figs. 6–13.)

Diagnosis.—Ethmolysian, with 4 gonopores (= *Trachyaster*). Outline elongate subovoid, with slight posterior truncation and deep anterior sulcus. Length 100;[1] greatest width, at level of apical system, which is eccentric in front, from 95 in young to 87 in adult; greatest height, at about 65 from anterior margin, from 63·7 to 71·8, average 68·6. Posterior truncation slopes upwards and inwards, so that periproct is visible from above. Posterior interradius subcarinate above, inflated on actinal surface. Margins of actinal surface rounded, so that ambitus is at one-quarter the height above base-plane. Summit depressed. Anterior ambulacral groove increases in depth towards margin and continues to peristome. Paired ambulacra increase in depth to one-third their length from apex, and then decrease to almost flush at ends of petals; II and IV subtend 110°, length of petals about 53 to 45, adult number of pore-pairs in series 26–28; I and V subtend 60°, length of petals about 32 to 39, adult number of pore-pairs in series 19–21. Pores conjugate, mostly elongate, outer twice length of inner. A line of miliaries on the intervening ridges. Peristome depressed anteriorly, with a projecting labrum. Periproct broadly lanceolate, more pointed above. Primary tubercles crowded on dorsal surface, larger on actinal surface, intermingled with secondaries on ambulacra I and V; bosses finely crenulate; scrobicular areas depressed, with circle of miliaries on abactinal surface, but with an inner raised rim on actinal surface. Miliaries closely set on all intervening space.

Description of the specimens.—A (B.M. registered E 4826) is well preserved, with some adherent hard marly matrix; the test,

[1] See footnote, p. 293. Length here = 21–32·3 mm.

however, is abraded on the actinal surface and on the right posterior quarter of the upper surface; this is the holotype. B (E 4827) is much more abraded, as well as cracked; C to O (E 4835–4846) are mostly well preserved, but G is crushed.

General Form.—The subovoid ambital outline is cut into by the anterior groove to a depth of 2·3 mm. in A, and 1·8 mm. in B, and is flattened posteriorly by a truncation about 9 mm. wide in A, 6·5 mm. in B. Length of A, 30·5 mm., of B, 25 mm.; greatest width, A, 26·6 mm., B, 22·1 mm.; greatest height, A, 21·9 mm., B, 18·2 mm.; distance of vertex from the anterior vertical plane in A, 19·5 mm., but since the test is here eroded, it may have been further back, as in B, where the distance is about 16·5 mm., the ratios to length = 100 being A, 64, B, 66. In determining the vertical anterior plane, ambiguity arises from the fact that the specimens are not bilaterally symmetrical, but all project forward more on the right; one must therefore measure from where this plane cuts the sagittal plane.[1]

Summit depressed. Interradii swollen, all forming a strong convexity, as seen in transversal section, then falling away rapidly to the ambitus, which is at one-quarter the height above the base-plane. In this species the base-plane[2] is touched solely by the swollen plastron; and, owing to the asymmetry above noted, equilibrium is attained in these specimens only when they have fallen over to the right; in measuring, therefore, the sagittal plane must be fixed at right angles to the base-plane. The vertex lies just opposite the middle of the posterior petals; from it the subcarinate interradius curves gently down to the summit of the posterior truncation.

Actinal surface.—Plastron inflated, especially posteriorly, with a tendency to carination. Margin equably rounded, except posteriorly in median line, in ambulacra I and V, which are slightly depressed, and in anterior sulcus. (Pl. XI, Fig. 12.)

Apical System.—Gonopores 4, conspicuous, circular; anterior pair smaller than posterior, and closer together. Genital plates of each side abut, pushing outwards oculars II and IV; but ocular III comes between the main portions of genitals **2** and **3**. Genital **2**, however, stretches backwards in a madreporite, between and far behind genitals **1** and **4**, also separating oculars V and I, while genital 3 sends a broad tongue down to the madreporite. The system is therefore compact and ethmolysian. Ocular pores very small. The centre of the system, or apical pole, is 13·8 mm. from anterior vertical plane in A, 12·4 mm. in B. (Pl. XI, Fig. 7.) In E is an abnormality, gonopore **2** being on the left of ocular III.

Ambulacra.—Anterior feebly developed; attains a width of 4 mm. in A. In the proximal 5 pairs of plates the pores are not distinguishable; in the next 7 pairs they are minute and wide apart;

[1] Since noting the asymmetry in *Hemiaster sudanensis*, I have detected it in specimens of the genus from widely separated localities and horizons. It can be no mere individual abnormality.

[2] See footnote, p. 293.

after that none are distinguishable. Pore-pairs, not conjugate, slightly oblique, the outer pores being adapical and depressed in a slight peripodium.

The paired ambulacra are relatively deeper and wider in B than in A, suggesting that B was female and A male. They are almost straight, subpetaloid, and asymmetrical, the anterior half of II and IV, the posterior half of I and V, becoming the narrower towards the apex. II and IV subtend 110°. Length of petal, in A, 13·5 mm. (distance to margin along curve being 19·5 mm.), in B, 11·3 mm. (distance to margin, 14·8 mm.). Greatest width in A, 3·8 mm. at about 4 mm. from distal end of petal; in B, 3·5 mm. at about 5·3 mm. from end. Width at distal end of petal, 2·3 mm. in A, 2·1 mm. in B. Deepest part of petal at 6 mm. from apical system. Poriferous areas broad, extending almost to outer margin of ambulacrum, especially on posterior side. Pores conjugate; elongate, except 2 adapical pairs in the posterior half, 7 adapical pairs in the anterior half, and the extreme distal pair, all of which are circular. Outer pore of each pair slightly more distal and twice length of inner pore. Height of ambulacrals, ·6 mm. in A, ·5 mm. in B. In A the pores lie in the distal half of each plate, and the proximal half is marked with a line of six miliaries; B differs in having the pores nearer the middle of the plate. Each series contains 28 pore-pairs in A, 26 to 27 in B. Interporiferous area narrow (·75 mm. in A) and slightly grooved. (Pl. XI, Fig. 10.)

Ambulacra I and V subtend 60°. Length of petal, in A, 10 mm., in B, 8·3 mm. Greatest width at about half the length, 3·2 mm. in A, 3·4 mm. in B. Width at distal end of petal, 2·2 mm. Each series contains 21 pore-pairs in A, and 19 in B; of these the 3 proximal in both specimens, the 3 distal in B, and the extreme distal in A are circular. In all other respects these ambulacra resemble II and IV.

Interradials.—As previously stated, B affords evidence of normal heteronomy in 1. The number of petal-ambulacrals abutting on an interambulacral of 1 in A is 6. The small labrum is succeeded by two large sternals, which swell up to the median line; at the end of the sternum, about 15·5 mm. from the peristome in A, the interradius curves gently round to the margin, where it meets the posterior truncation. These structures are more clearly shown in the Tamaské specimens (Pl. XI, Fig. 12).

Peristome.—In A the transverse diameter is 3·2 mm., the sagittal, 1·6 mm. The anterior sulcus is continued right up to its anterior margin, which is 7·6 mm. from the anterior vertical plane. Anteriorly and laterally is a slightly raised rounded rim. Posteriorly, the labrum projects over the opening, and is raised about 1·4 mm. above the level of the anterior lip. (Cf. specimen I; Pl. XI, Fig. 12.)

Periproct.—Vertically elongate, broadly lanceolate, more pointed above, situate at upper end of posterior truncation, at about 11·5 mm. above base-plane in A, with length 4·8 mm., and width 3·3 mm.

Ornament.—Primary tubercles best preserved on the sides of the anterior groove, where they are larger, and on its floor, where they

are smaller. They appear to have covered thickly the whole dorsal surface. On the actinal surface they are rather larger, and, on the periplastronal ambulacra, are interspersed with secondaries. The bosses are low, rounded, and where well preserved finely crenulate. No signs of perforation can be traced, but this is not enough to prove that the tubercles were not slightly perforate. Traces of the peripetalous fasciole are clearly seen in A, crossing the anterior groove at 15 mm. from the apex, and at the end of petal V, well beyond the poriferous area; also, less clearly at the end of petal IV. There is not the smallest trace of any other fasciole, but all regions where such might be expected are crowded with tubercles.

[On the other hand, all the Tamaské specimens, except the crushed and abraded G and N, show the lateral fasciole distinctly. It is linear, but incised, continues the line of the peripetalous fasciole from the ends of petals II and IV, till opposite the ends of petals I and V; here it dips to nearly the base of the posterior truncation. The posterior tract of the peripetalous fasciole leaves the main line about the middle of interambulacral series 1*b* or 4*a* respectively, runs parallel to petals II and IV, then parallel to the lateral fasciole, till it reaches the ends of petals I and V, whence it cuts straight across the carina of 5 (Pl. XI, Fig. 13).]

Relations to other species.—The number of species of *Hemiaster* is large, but the majority are either distinctly ethmophract, or, if ethmolysian, have less than 4 gonopores. Taking those that remain, it appears that our species differs from them all in the greater elongation or narrowness of the adult test, and from most also in the deep excavation of the ambitus by the anterior sulcus, while, from the few that have this character, it differs in the shallowness of the same groove near the apex. One or other of these features, combined with others mentioned in the diagnosis, separates it so definitely from all species of *Trachyaster* type, that detailed comparison is needless.

In general form the Sokoto fossils approach more nearly some species of *Linthia*, and, in view of a possible confusion, the differences may be pointed out. Thus *Linthia bisulca* Peron & Gauthier has petals more equal in size and a smaller posterior truncation; Cotteau's figure of this (Pal. Franc., tom. cit., pl. lxxx, fig. 5) shows neither the heteronomy said to characterise *Linthia* nor that found in *Hemiaster*. In *L. Cotteaui* Tournouer and *L. dubia* Cotteau, the posterior truncation is vertical and the periproct invisible from above; in the latter also it is transversely elongate. *L. Pomeli* Cotteau is rather elongate, but the angle subtended by ambulacra II and IV is greater, and petals I and V are much longer. *L. Ducrocqui* Cotteau is somewhat elongate, but width : length :: 95 : 100; the posterior truncation slopes downwards and inwards so that the periproct is invisible from above; the pores are circular and not conjugate; for this species also Cotteau's figure (tom. cit., pl. lxvi, fig. 3) does not show ancient heteronomy. *L. sindensis* Duncan & Sladen has a greater slope to its posterior truncation, and width : length :: 103 : 100. No other species of *Linthia* seems to present greater resemblances than do those mentioned.

Evidence as to age.—The genus *Hemiaster*, in its typical ethmophract form, ranges from Cretaceous times to the present day,

but the ethmolysian form did not appear, so far as we know, till the Eocene period. These specimens therefore confirm the view that the stratum from which they came is of Tertiary age. More than this it were not safe to say.

General Geological Conclusions.

The fossils collected by Captain Lelean had already been determined by Mr. Bullen Newton and myself, and the importance of their discovery recognised, before I learned that attention had previously been drawn by Professor A. de Lapparent[1] to similar fossils collected in the same district by French officers. The following are the main facts recorded by him.

Echinoids, which may or may not have been of the same age, were collected by the late Captain Pallier near Zinder [450 km. W. of Lake Chad, and about the same distance E. of Sokoto], but have since been lost. Subsequently Captain Gaden collected at Tamaské, 400 kilometres west of Zinder [and apparently not far from Garadimi], a Nautilus allied to *N. Lamarcki* of the Calcaire grossier, five casts of *Nerita* (*Velates*) *Schmideliana*, belonging to the variety characteristic of the Middle Eocene, and four Echinoids determined by Mr. Victor Gauthier as one *Plesiolampas* sp. nondescr., one *Leiocidaris*, badly preserved but clearly of Tertiary age, and two specimens of *Linthia* "so closely resembling *L. Ducrocqui* Cotteau, of the Eocene limestone of Saint-Palais (Charente-Inférieure), that it is hard to separate them from it." It appears that the *Plesiolampas* and *Leiocidaris* are not well enough preserved to be capable of description; otherwise Professor de Lapparent would doubtless have included in his paper a recognisable diagnosis. I have, therefore, thought it advisable to publish a description of the excellent specimens brought home by Captain Lelean. As for the specimens of *Linthia*, it occurred to me that Mr. Gauthier might have had before him the same species as that found by Captain Lelean and described above as *Hemiaster sudanensis*. But, for the reasons already given, I am unable to consider our specimens as resembling *L. Ducrocqui*, or even as belonging to the genus *Linthia*.

[Examination of the Tamaské specimens presented by Captain Foulkes necessitates no modification of the preceding remarks.]

It is therefore interesting to find that, just as the French and English observers in the field independently made similar discoveries, so the palæontologists of the two countries have independently arrived at similar conclusions, each confirming the other.

To French observers are also due other recent discoveries, which throw much light on the geological history of the present specimens. The occurrence of *Plesiolampas*, a genus hitherto unknown outside Sind, suggests a continuous westward extension of the Eocene Indian Ocean; and this idea is confirmed by an Egyptian fossil of the same

[1] "Sur les traces de la mer lutétienne au Soudan," C.R. Acad. Sci. Paris, cxxxvi, pp. 1118–1120; 11 May, 1903; and "Sur de nouveaux fossiles du Soudan," tom. cit., pp. 1297–8; 2 June, 1903.

age, identified by Mr. Gauthier as *Plesiolampas*. That a large part of the intervening area was filled by the Lutetian sea is proved by the occurrence of *Nautili* and Echinoidea, believed by Captain Gaden to be of the same species, at Zinder and in Damergu, where the beds are more marly. Professor de Lapparent further recalls the occurrence of *Echinolampas* of Lutetian age at Dakar [near Cape Verde], and supposes the inward extension of an Atlantic Gulf on this side. If the Eocene limestones and marls ever extended northwards, they have now been denuded, and in their stead are found outcrops of Cretaceous rock, which have in Damergu yielded to Captain Gaden an ammonite allied to the Turonian *Mammites* and *Vascoceras*, while 450 km. north of Lake Chad, at Bilma, Colonel Monteil found an echinoid of Maestrichtian age, described by Mr. V. Gauthier[1] as *Noetlingia Monteili*. This fossil also indicated a connection with north-west India. The same connection may have remained open for several geological ages; and while, on the one hand, the Lutetian sea may have extended northwards over Bilma and even into the Libyan desert, so on the other hand the Cretaceous rocks may pass southwards and underly the Lutetian of Sokoto and Damergu.

The modesty of the English officers of the Niger-Chad Boundary Commission will be the less offended, and my own awkwardness the less exposed, if Professor de Lapparent will permit me to borrow his concluding paragraph, all but one word: "Je crois devoir terminer en exprimant une vive gratitude à l'égard des vaillants officiers qui, sous un ciel de feu, au milieu de fatigues et de préoccupations de toute sorte, ne négligent pas de recueillir au passage, pour le plus grand bien de la Science . . . . . , des documents d'un pareil intérêt."

DESCRIPTION OF PLATE XI.

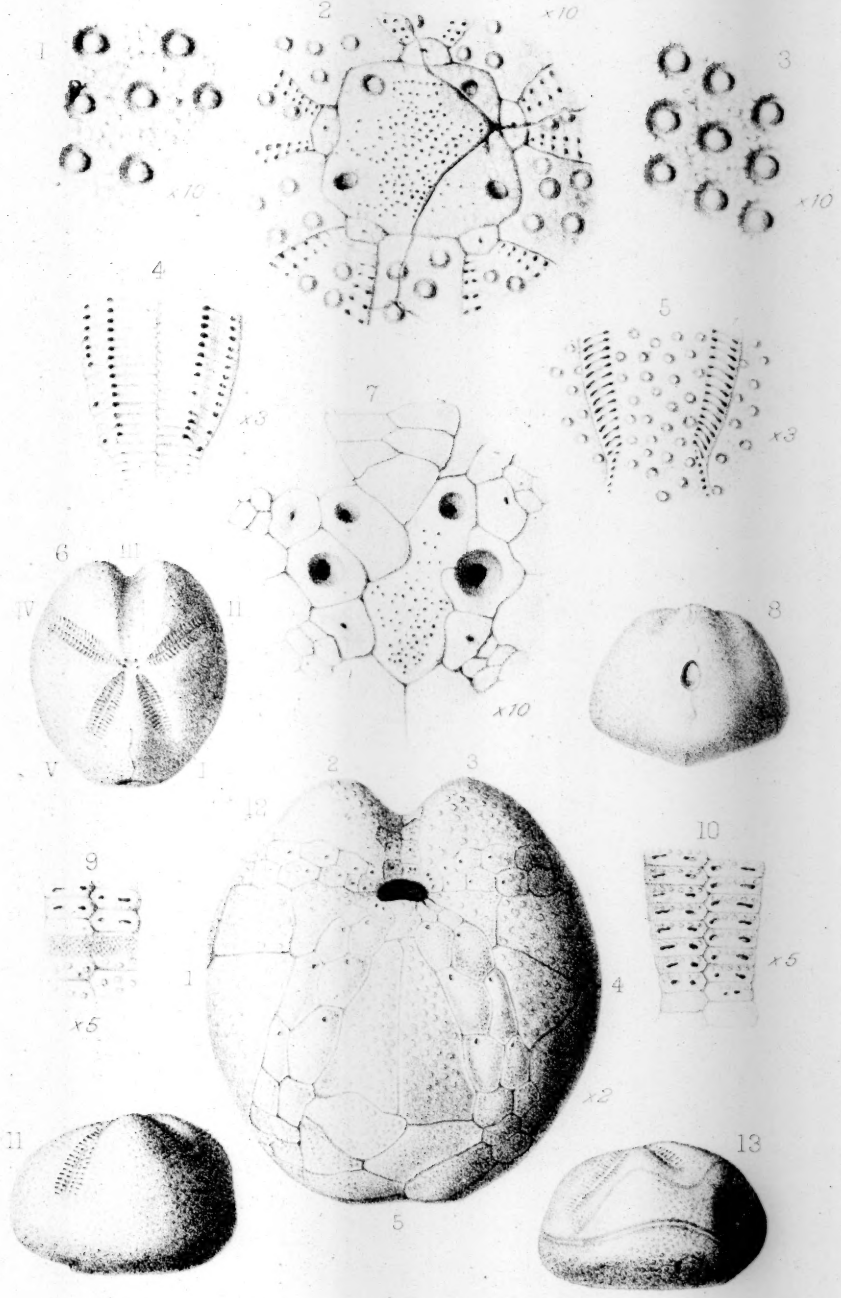
Plesiolampas Saharæ.

Fig. 1. Tubercular ornament on an interradius of abactinal surface of D: × 10 diam.
,, 2. Apical system of A: × 10 diam.
,, 3. Tubercular ornament on an interradius of actinal surface of D: × 10 diam.
,, 4. Distal end of petal IV of A, surface abraded: × 3 diam.
,, 5. Distal region of petal III of A: × 3 diam.

Hemiaster sudanensis.

Fig. 6. Abactinal surface of A: nat. size.
,, 7. Apical system of A: × 10 diam.
,, 8. Posterior view of A: nat. size.
,, 9. Distal end of petal V of A, showing fasciole: × 5 diam.
,, 10. Distal region of petal II of A: × 5 diam.
,, 11. Left side view of A: nat. size.
,, 12. Actinal surface of specimen I, mainly to show normal heteronomy: × 2 diam.
,, 13. View of II from left posterior interradius, to show peripetalous and lateral fascioles: nat. size.

[1] Bull. Soc. Geol. France (4), i, p. 189; 1901. See also A. de Lapparent, C.R. Acad. Sci. Paris, cxxxii, p. 388; 1901.



G.M. Woodward del. et lith. West, Newman imp. London.

Eocene Echinoids from Sokoto.

IV.—Note on a new Fossiliferous Limestone in the Upper Culm Measures of West Devon.

By Inkermann Rogers, and E. A. Newell Arber, M.A., F.L.S., F.G.S.

At the present time we are only fully acquainted with the geology and palæontology of one division of the great Carboniferous Series developed in Devon and the adjacent counties, the Lower Culm Measures. This division, while representing only a small fraction of thickness of the Culm Measures as a whole, is of special interest both lithologically and palæontologically, as was shown by Messrs. Hinde & Fox[1] in an admirable paper published in 1895. Above the limestones and cherts of the Lower Culm Measures lie the great thickness of sandstones and shales which constitute the Upper of the twofold primary division of these rocks instituted by Sedgwick & Murchison[2] in 1840. The Upper Culm Measures occupy an area of more than 1,000 square miles, and are of Upper Carboniferous age.

With the exception of the researches of the late Townshend Hall, and more recently of Mr. Ussher, comparatively little has been added to our knowledge of these beds since the days of Sedgwick & Murchison, and of De la Beche. An inquiry with regard to the palæontology, and more especially the palæobotany, of these rocks has, however, been in progress for some time past, with the result that sufficient material has been gathered for a contribution to the fossil flora of the Upper Carboniferous rocks of Devon, which it is hoped will be published shortly by one of us. While examining the sandstones and shales of this series, other discoveries have been made, incidental to the work of collection of plant-remains. Among these the discovery of fossiliferous calcareous nodules, and, in one locality, of a limestone band, seems to warrant special notice.

So far no limestones have been known to occur in the Upper Culm Measures. Even in the Lower Carboniferous portion of the Culm Measures the general absence of calcareous deposits is somewhat sharply contrasted with the Lower Carboniferous sequence developed elsewhere in Britain. Limestones do, however, occur in this series. They form inconstant and impersistent bands, seen at Swimbridge and Venn near Barnstaple, and in other localities, and are generally believed to underlie the Coddon Hill beds, though Mr. Ussher[3] is inclined to regard them as superior to the cherts. On the other hand, the only calcareous sediments known from the Upper Culm Measures are the calcareous shales and shaly nodules containing fish and Goniatite remains occurring at Instow, near the junction of the Taw and Torridge, which were described in 1876 by the late Townshend Hall[4] in the Geological Magazine.

The Instow beds lie, so far as we have been able to ascertain, near the base of the Upper Culm Measures, and, although the

[1] Hinde & Fox: Quart. Journ. Geol. Soc., vol. li (1895), p. 609.
[2] Sedgwick & Murchison: Trans. Geol. Soc., ser. II, vol. v (1840), p. 633.
[3] Ussher: Proc. Somerset Arch. and Nat. Hist. Soc., vol. xxxviii (1892), p. 121.
[4] Hall: Geol. Mag., Dec. II, Vol. III (1876), p. 410.

district has been thoroughly searched by one of us, we have been unable to find any other calcareous rocks. Such deposits have also proved to be absent on the higher horizon in which the impure coal or culm occurs in the neighbourhood of Bideford. The thorough examination of these beds, which has been made during the collection of the plant-remains already mentioned, has not resulted in the discovery of any trace of a calcareous nodule.

More recently attention has been turned to yet higher beds in the Upper Culm Measures, which are stated by Mr. Ussher[1] to be somewhat dissimilar to the Culm Measures of the Bideford district, and which he has distinguished as the *Eggesford Grits*. In this work we have been assisted by a grant recently made to one of us by the Royal Society Government Grant Committee, and we may here express our great indebtedness for the removal of many difficulties by this means.

The Eggesford grits of Mr. Ussher consist of even-bedded sandstones and shales, and these may be studied in the fine coast-section between Portledge Mouth and Windbury Point, a district which may be conveniently termed the Clovelly district. This portion of Devon is practically unexplored geologically. With the exception of a brief notice of the Culm Measures near Clovelly, published by Conybeare[2] in 1814, there is, so far as we are aware, no evidence to show that it has ever been studied in detail. It may be pointed out that Conybeare makes no mention of any calcareous deposits, although such occur within a few yards of Clovelly pier. Pengelly[3] and Townshend Hall also overlooked these beds, although well acquainted with the district.

Calcareous nodules have recently been found in several localities along the coast to the west of Clovelly. They occur a short distance from Clovelly, also below Gallantry Bower (on the south-east side), and they have been found in association with the limestone described here near Mouthmill, and also beyond Mouthmill in Beckland Bay on the western side of Windbury Point.[4] They are found in certain beds of shale, usually of 1–2 feet in thickness, which alternate with the sandstones. The nodules are oval in form and of all sizes, a rather large nodule measuring nine inches or more along its greater axis. They effervesce freely with acid, and are crowded with casts of Goniatites, similar to those mentioned below, which are often preserved in calcite, although usually in rather indifferent preservation. The thickest of these conglomeratic beds is that associated with the limestone band at Mouthmill.

In one locality the nodular beds are overlain by a thin band of limestone,[5] which is of special interest as being the only limestone

[1] Ussher: Trans. Inst. Min. Engineers, vol. xx (1901), p. 362; see also the excellent geological map of Devonshire on pl. xvi.

[2] Conybeare: Trans. Geol. Soc., ser. 1, vol. ii (1814), p. 495.

[3] Pengelly: Trans. Devon Assoc., vol. xvii (1885), p. 425.

[4] The Western Coast Section has not as yet been explored, but calcareous nodules have been found a short distance to the south of Hartland Point.

[5] The limestone was discovered by Mr. Rogers in August, 1903, when searching for plant-remains on my behalf.—E. A. N. A.

known in the Upper Culm Measures. Some 300 yards from Blackchurch Rock and Mouthmill, and about one and a half miles by the coast to the west of Clovelly, the even-bedded grits and shales, which in this neighbourhood consist of alternating beds of a few feet in thickness, are thrown into a well-preserved sharp anticlinal fold. This anticline differs from the others which are found all along this coast, by the fact that a *thick* bed of splintery shale occurs between the grits, and resting on this shale is an inconstant and impersistent band of limestone. The axis of the anticline lies roughly east and west. The crest is faulted with a downthrow of one or two feet, or perhaps more, to the north; the faulting being obscured in the lower portion. At the base of the anticline, a fine-grained sandstone is seen, similar in character to the other sandstones in the neighbourhood. Next in order comes the thick bed of shale, which is somewhat obscured below, and consequently its exact thickness is difficult to ascertain. It is probably more than ten feet thick. Near the top of the shale, on the northern side of the anticline, numerous calcareous nodules occur. These begin at a distance of two to three feet from the summit of the bed, the lower nodules being smaller and more scattered, whereas those near the top of the bed are larger and crowded together. On the opposite side of the anticline the nodules are equally prominent and abundant.

On the northern side, the highest bed seen is a dark-coloured limestone, from 9 to 20 inches in thickness, resting on the conglomerate described above. The limestone is also seen near the crest on the southern side of the anticline, where it is overlain by sandstones and shales of the usual type. It is, however, impersistent, and does not occur at the base of the anticline on this side, where the sandstones rest directly on the shales with nodules. A microscopic section of the limestone has been very kindly examined for us by Mr. Howe, who has confirmed the conclusion that this rock may be correctly termed a limestone. It may be also remarked that there appears to be here a gradual transition from an arenaceous rock with little or no calcareous material to a fairly pure limestone. Whether this is really the case or not, we must leave to those who possess a more special knowledge of petrology to determine.

The limestone and the calcareous nodules contain numerous casts of Cephalopoda and Lamellibranchs. We are indebted to Mr. Crick, and to Dr. Wheelton Hind, for the determination of the following species:—

Gastrioceras carbonarium (von Buch). *Dimorphoceras Gilbertsoni* (Phill.).
Gastrioceras Listeri (Martin)? *Orthoceras*, sp.
Pterinopecten (*Aviculopecten*) *papyraceus* (Sow.).

The same species of *Gastrioceras* were obtained by the late Townshend Hall from the calcareous shales at Instow, already mentioned; and his specimens are now in the Geological Department of the British Museum (Nat. Hist.).[1] These species have also been

[1] Registered numbers C. 1613 and C. 1613*a*, see Hinde & Fox, ib., p. 655, table ii.

found by us in the same beds at Instow quite recently. These, and two fish-remains from Instow, *Cœlacanthus elegans*, Newb., and *Elonichthys Aitkeni*, Traq., also in the British Museum [1] are practically all the determinations, with the exception of plant-remains, which have so far been made from the Upper Culm Measures of Devon.

In conclusion, we believe that the calcareous nodules and the limestone of the Clovelly district belong to a much higher horizon in the Upper Culm Measures than the Instow beds. Whether the nodules, now found in a number of scattered localities in the former, are really confined to a single bed, or occur on different, but not distant, horizons, we are unable to ascertain, as the severe folding, faulting, and crushing which the rocks have undergone render it rarely possible to trace any bed for more than a few yards. At any rate, the occasional occurrence of calcareous nodular beds seems to be in some measure characteristic of the Culm Measures of the Clovelly district.

It would seem that, in Devonshire, marine Cephalopoda such as *Gastrioceras carbonarium*, which are usually regarded as more restricted vertically than other palæontological types, have a considerable range in the Upper Culm Measures, occurring in what are probably the lowest and highest beds of that series. It may be also pointed out that the occasional occurrence of marine calcareous bands is an important point of agreement between the Upper Culm Measures and the Coal-measures of other British coalfields, more especially those of North Staffordshire [2] and South Lancashire.[3]

V.—On the Origin of certain Pegmatite Veins.

By J. Vincent Elsden, B.Sc., F.G.S.

DURING a visit to the South of Sweden in the Summer of 1902 I noticed the frequent occurrence in granite of pegmatite veins showing a succession of small but very regular foldings, which, however, did not affect the parent rock. In sett quarries where these folded veins existed the rift of the rock was perfectly regular on each side of the pegmatite, proving conclusively to my mind that the contortion of the veins took place prior to the consolidation of the main mass. The granite of this district occupies a wide area, and possesses a very uniform mineralogical constitution, although it varies much in texture between a rather coarse-grained granitite and a fine-grained, compact, gneissose rock possessing well-marked foliation. The pegmatite veins are fairly numerous, but are generally rather insignificant in width, occasionally thinning out to mere streaks not more than a few inches in thickness.

The origin of pegmatite veins has been much discussed, but most of the various theories hitherto advanced almost invariably attribute

[1] Registered numbers P. 6100, P. 5379, and P. 6268.

[2] Ward: Geol. Mag., Vol. II (1865), pp. 234 and 286.

[3] Hull & Green, Trans. Manch. Geol. Soc., vol. iii (1862), p. 348; and Hull & Salter, "Geology of the Country round Oldham," 1864, p. 64.

them to the infilling of cracks and fissures formed subsequently to the consolidation of the parent rock. Charpentier, in his examination of the Pyrenees in 1823, conceived the view that pegmatites are true fissure veins, injected by portions of the still fluid part of the magma from below. This view has been largely adopted by the French geologists, and also by De La Beche in this country, and by Naumann, Gümbel, and others in Germany. Such veins would seem to form the "Injectionsschlieren" of Reyer,[1] and are similar to what are sometimes termed contemporaneous veins. De Saussure, G. vom Rath, and others, however, maintained that these veins were deposits from watery solutions; while Forchhammer, Sandberger, and Credner advocated the theory of lateral secretion, involving the assumption that pegmatite veins are true fissures filled up with minerals leached out from the surrounding rock. Rosenbusch[2] associates pegmatite veins with drusy and miarolitic structures, or vein-like cavities filled up by secondary crystallisation, a view also briefly suggested by Teall.[3] Later observers have modified these theories with a view to the explanation of the marked acidity of pegmatite veins in comparison with that of the parent rock. Thus Brögger, in his well-known work on the rocks of the Christiania district,[4] found evidence to show that these veins represent true eruptive outpourings, the last *aufpressungen* of a differentiated magma basin. This view somewhat corresponds to the *hysterogenetische schlieren* of Reyer, or the *ausscheidungstrümmer* referred to by Kalkowsky[5] in his description of the pegmatites in the granulite of Saxony. Later observations of Messrs. Gunn, Hinxman, Barrow, Kynaston, Clough, Cunningham-Craig, and Wilson, in the Highlands of Scotland,[6] have led in the majority of cases to the conclusion that the pegmatite veins are subsequent intrusions, although in a few cases they are referred to as of segregative origin; but whether these segregations were of a magmatic type or merely the results of subsequent metamorphism is not always clearly indicated. Keilhau, writing in 1838 on the Christiania pegmatites, attributed them to simultaneous separations of the surrounding eruptive mass, and not to the filling up of fissures; but no one, so far as I am aware, has described evidence of the original existence of such veins in the form of acid streaks in a viscous magma, prior to consolidation.

The remarkable agreement in the characters of pegmatite veins in widely separated areas points to some general law governing their mode of origin. It is, therefore, somewhat strange that the views advanced concerning their formation should still remain so much at variance. It seems at least certain that the pegmatites of Blekinge province, in Sweden, present peculiarities which absolutely preclude the suggestion that these are subsequent fissure injections of the

[1] See Zirkel, "Lehrbuch der Petrographie," vol. i, p. 787 et seq.
[2] Mikroskopische Physiographie d. Mass. Gesteine, ii, p. 39.
[3] "British Petrography," p. 291.
[4] "Die Mineralien der Syenit pegmatitgänge," etc., Leipzig, 1890.
[5] Zeit. d. d. geol. Ges., vol. xxxiii (1881), p. 653.
[6] See "Summary of Progress," 1899, 1900, 1901, 1902.

type described by Brögger in the Christiania district. Unfortunately the time at my disposal did not allow an exhaustive examination of this large district, and my present remarks are written rather with the hope of eliciting further information than with any claim to the establishment of a final conclusion.

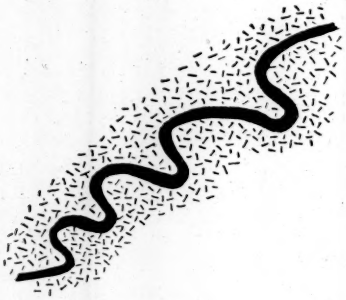


Fig. 1.—Contorted pegmatite vein in granite, Gungvala, near Carlshamn, Sweden. Scale, 1 inch = 2 feet.

At Gungvala, on the railway running inland from Carlshamn, I saw thin pegmatite veins, often not more than a few inches wide, sharply folded as in the accompanying diagram (Fig. 1). The amplitude of the folds is seldom more than a couple of feet, but

Fig. 2.—Folded pegmatite in a sett quarry, Gungvala, Sweden. The parallel lines are joint planes. Scale, 1 inch = 10 feet.

there is no sign that these folds influence the parent rock. A striking example is shown in Fig. 2, where the folds taper downwards, diminishing in amplitude, while the veins themselves contract in width. The junction between the granite and pegmatite is clean and complete, without any druses or other interruptions that could

be discovered. As previously stated, well-defined rifts exist in the granite. These rifts run not only parallel to the joint planes, but also along well-defined though faint foliation planes in the granite, usually cutting transversely across the direction of the folded pegmatites. I do not, therefore, think it possible that there can be any mistake in the conclusion that the folding of the pegmatites occurred before the main mass crystallised.

In the Mörrum district, a few miles to the south-west, similar phenomena can be observed, but here the pegmatites are sometimes disposed in very regular planes, about six feet apart, parallel to the well-defined foliation in the parent rock. Whether these are uncontorted, or whether they owe their appearance to being cut transversely, viz., parallel to the axes of the folds, is not certain. At Matvik, on the coast, a few miles east of Carlshamn, I noticed similar veins of pegmatite, parallel to highly inclined foliation planes, dividing so as to enclose a 'horse' of the country rock, but without any disturbance of the regular foliation of the parent mass. Very striking relations between the folded veins and the foliation planes of the granite were seen at Külleron, to the west of Carlshamn. Here the appearance was as represented in Fig. 3. It is difficult to

Fig. 3.—Contorted pegmatite in gneiss, Külleron, near Carlshamn, Sweden. The double arrow indicates direction of foliation of the gneiss. Scale, about $\frac{1}{35}$.

escape from the conclusion that the pressure which induced the foliation also operated in the production of the contortions in the pegmatites while the mass was still in a viscous condition. Nor can any theory of subsequent vein filling adequately account for the phenomena. It must be mentioned, also, that the pegmatite veins are not themselves foliated, which is probably to be attributed to the fact that the solidification of the veins took place subsequently, under different conditions from those prevailing during the crystallisation of the main rock, as I shall endeavour to explain later. This result might readily be produced if we assume that the foliation was produced by a gentle shearing force at a time when the minerals of early consolidation were already formed, while the substance of the veins still remained in a state of viscous fluidity. This would also account for phenomena noticed in the neighbouring island of Günon, where the foliation planes appear to be slightly deflected by contact with the margins of the pegmatites. Nearer Carlshamn I saw many

other examples of similar contortions, as also in the district around Sölvesburg, from which locality, at Siritorp, I noted the appearance represented in Fig. 4.

The explanation demanded by these phenomena seems to be that the granite magma was traversed by streaks and bands of different composition from it. Now a streaky or banded magma can only occur in one of two ways. It may be due to the unequal mixing of the magma in the first instance, forming the so-called *constitutionsschlieren*, or *mischungsschlieren* of Reyer; or it may be caused by an originally homogeneous magma becoming streaky in the final stages of its existence in a molten state. With regard to the first of these causes, we are reminded of the phenomena observed in the process of glass manufacture, and of the difficulty experienced in obtaining glass free from striation or wreath. It would, however, be very difficult, on such an assumption, to explain why the striæ are so uniform in mineralogical character; so that we are driven to a consideration of the second hypothesis.

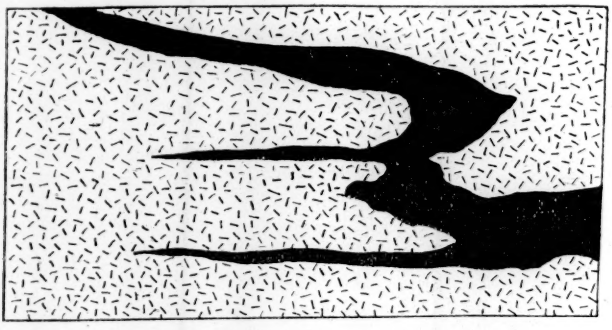


Fig. 4.—Pegmatite vein in granite at Siritorp, near Sölvesburg. Scale, 1 inch = 4 feet.

An examination of a number of thin slices prepared from the above-mentioned rocks throws light upon the order of the different consolidation phases. The normal rock has a simple constitution. Biotite and sphene are the chief products of the earliest crystallisation; while felspar, chiefly microcline, and quartz seem to have struggled together for the mastery in the final stages. Accessory minerals, such as occasional hornblende, some magnetite, apatite, and a little zircon do not occur in sufficient quantity to affect the character of the rock, and the same may be said of certain pneumatolytic minerals, of which chalcopyrite is the most conspicuous example. Dark basic secretions are abundant, and are distinguished, like the pegmatites, by evidences of considerable movement during consolidation. They are frequently drawn out into irregular elongated forms, and at Hasteryd they may be seen pressed out into lenticles along the foliation planes. These dark patches are typical quartz diorites, containing an abundance of well-formed brown

hornblende, biotite, plagioclase, some orthoclase, and a little quartz. No microcline was observed in the slices examined. These dark segregations, therefore, differ essentially from the normal rock, and may be safely regarded as a result of the first phase of consolidation. The deformation of these basic secretions is in accord with previous observations in other localities,[1] and would be expected to occur under the influence of magmatic movements. Although these dark patches are usually regarded as true results of magmatic segregation, the *primären ausscheidungsschlieren* of Zirkel, it may be mentioned that Reyer and others regard even these as having resulted from an original imperfect mixing of a more or less heterogeneous magma. The junction between them and the normal rock is well defined, and in a slide showing the contact the transition is sudden from the diorite to the microcline granitite.

Passing now to the pegmatites, these are very coarsely crystalline mixtures of large microcline crystals and quartz, representing the pegmatite of Haüy, although there is not any conspicuous orientation of the quartz. Accessory minerals are not altogether wanting, and in some examples the pneumatolytic species seem to be more abundant than in the parent rock, a feature which was also noticed by Brögger in the Christiania district.

It is obviously conceivable that we might consider these veins to be a product of magmatic differentiation, which began with the consolidation of the dioritic patches, and concluded with the streaks and veins of pegmatite, something after the nature of the streaks of low freezing eutectic observed in some alloys. But it would be difficult on this assumption to account for the regular, wavy contortions, which could scarcely have been formed otherwise than in a still viscous mass. On the other hand, differentiation in a liquid magma of such a nature as to develop such streaks is at least purely conjectural. We do not yet know the limits of miscibility of silicate magmas, nor whether it is possible for a binary mixture, containing quartz and felspar, to segregate in distinct layers in the midst of an ordinary ternary granitic magma. At the same time, physical chemists are gradually extending our knowledge of the series of liquids which only mix in all proportions between certain well-defined limits of temperature,[2] as, for example, in the case of molten zinc and lead. But in the present state of our knowledge it would be unsafe to assume that a magma can become streaky by mere hysterogenetic differentiation.[3]

But another explanation is possible. The magma may have been subjected to an invasion by streams from contiguous areas. These currents, if regarded as the acid residuum forced out from regions where partial consolidation had already taken place, would be differentiated as regards the liquid which they invaded, and might

[1] See Frosterus, "Über ein neues Vorkommniss von Kugelgranit," etc.: Tschermak's Min. und Pet. Mittheilungen, xiii (1892), p. 177.

[2] See Findlay, "The Phase Rule," chap. xiv (1904).

[3] Cf. Morozewicz, "Experimentelle Untersuchungen über die Bildung der Minerale im Magma": Tschermak's Min. und Pet. Mittheilungen, xviii, pp. 232–3.

easily form such streaks as would, on crystallisation, form pegmatite veins. Slowness of diffusion in a viscous mass would prevent any appreciable mingling of the solutions, except perhaps at their margins. They would form thin bands, like a mixture of syrup and water, and they would suffer deformation and contortion in consequence of any magmatic movements to which they might be exposed. This would explain the formation of contorted bands in the midst of an uncontorted rock.

We have next to account for their coarsely crystalline texture, a feature usually taken to indicate slow cooling. Slowness of growth undoubtedly tends to the development of large crystals; for owing to the influence of surface tension it can be shown that in any solution in which crystals are forming, while the solution is supersaturated with regard to the larger crystals it may be unsaturated with regard to the smaller ones. The latter, therefore, may be resorbed and deposited upon the former, which will then continue to grow at the expense of their smaller brethren. But it may be taken as an established fact that the formation of large crystals depends upon other factors than the rate at which cooling takes place. Thus, at Öfvra Trensum, in the neighbourhood of Carlshamn, may be seen a well-marked irregular junction between a very fine-grained blue granite and a coarse porphyritic pink rock. These were evidently part of one and the same cooling mass, but the junction shows no relation to any conceivable isothermal planes. Variations in texture are, indeed, a common phenomenon in plutonic masses. It may be safely assumed that the pegmatites crystallised at a later stage than the parent rock. Whether we look upon them as true eutectic mixtures or not, the circumstances of their origin, as assumed above, would indicate a freezing-point lower than that of the main mass. Pressure probably plays an important part in crystallisation, but we are only beginning gradually to realise the direction of its influence. The experiments of Oetling[1] seem to show that the chief rôle of pressure is to promote superfusion. Now Tammann[2] has shown that the velocity of crystallisation increases with degree of superfusion up to a certain maximum, and then diminishes. The larger and more perfect crystals are formed near the minimum of superfusion. Another factor which comes into play is the number of crystalline nuclei present, upon which the influence of certain catalysers or 'agents mineralisateurs' must be considered. I am aware that the action often ascribed to these mysterious agencies has been called in question by some recent observers, notably by Lagorio and Morozewicz; but our knowledge of the ionic dissociation of fused salts is still so incomplete that for the present it would seem advisable to retain as a useful hypothesis the conception of catalytic action by such agents under certain conditions.

[1] "Vergleichende Experimente über Verfestigung geschmolzener Gesteinsmassen unter Erhöhtem und normalem Druck": Tschermak's Min. und Pet. Mittheilungen, xvii, p. 331.

[2] Zeit. fur physikalische Chemie, xxvi (1898), p. 307.

In the case of these pegmatites it is probable that the contraction of the parent rock on consolidation would diminish the pressure upon the still fluid veins. These would, therefore, at last consolidate under conditions of temperature, pressure, and also concentration, very different from those under which the main mass crystallised, and a marked difference in texture might then be expected.

On the whole, I am inclined to think that we have in these Blekinge pegmatites merely a local modification of Brögger's theory. The contorted pegmatites may indeed be the 'aufpressungen' of a differentiated magma; not, it is true, in this case, invading cracks and fissures of a consolidated rock, but streaming into the still fluid portions of a neighbouring molten mass. But while differentiation has thus played an important part in the process, it must not be overlooked that, if this view should prove correct, the final result was, to a still larger degree, due to the imperfect integration of a streaky magma.

VI.—The Jurassic forms of the 'genera' *Stomatopora* and *Proboscina*.

By W. D. Lang, B.A., F.Z.S., of the British Museum (Natural History).

After many months' work at the Polyzoa in the British Museum, the author has been driven to the conclusion that the relationships of the Jurassic forms of the 'genera' *Stomatopora* and *Proboscina* have been misunderstood, and that consequently their present arrangement, as put forward in the British Museum Catalogue, is unsatisfactory.

A detailed examination of all the material available has resulted in the following conclusions:—

1. The division of the forms into the genera *Stomatopora* and *Proboscina* is unnatural.

2. The development of a colony (the *zoarium* of Polyzoa) is comparable with and follows the same laws as the development of the individual (the *zoœcium* of Polyzoa).

3. Therefore the diagnosis of a form, whether 'species' or 'circulus,'[1] is incomplete, and for practical purposes useless, unless the part of the zoarium with respect to its age is specified.

4. In the 'genera' *Stomatopora* and *Proboscina* the method of branching is of paramount importance.

It is intended to take each of the above conclusions and explain by what observations it has been reached, and to what rearrangement of the specimens it tends. To upset the existing order may seem revolutionary, but if by this means a natural grouping is arrived at, if evolutionary series are found, such as have been demonstrated among Brachiopods and Ammonites, if when a new form occurs it is found to fit into one of these series, then the orderly result will justify the radical alterations.

[1] J. W. Gregory: Brit. Mus. Cat. Jur. Bryozoa, 1896, p. 22; and Mem. Geol. Surv. Ind., 1900, ser. ix, vol. ii, pt. 2, pp. 17–22.

The first point, namely, the artificiality of the genera *Stomatopora* and *Proboscina*, has already been discussed by Gregory,[1] who, while admitting that the line which divides them is arbitrarily drawn, since it is obvious that the forms constitute a natural series, maintains that, if this be done, the genera *Berenicea*, *Reptomultisparsa*, *Idmonea*, *Diastopora*, *Entalophora*, and *Spiropora* must for similar reasons be merged. And since the retention of these genera is convenient for working purposes, he leaves them as they are. But he does not suggest, what the author believes to be the case, that these 'genera' are polyphyletic in origin, and that in some cases a given species of *Proboscina* may be at the head of a series of forms, the simplest of which are undoubted *Stomatopora*.

In such a case the series would form a natural genus parallel with, and having a common origin with, other series. These would constitute new genera, starting from the point at which they branched from the first series.

Given sufficient material, such series can be found, and in one or two cases have been found, by tracing the development of the different characters of a colony from the first zoœcium, and by this means finding genetic relationships.

And this question of zoarial development leads to the second proposition, namely, that the development of the colony is comparable with and follows the same laws as the development of the individual.

It was the observation of this fact that led the author to doubt the validity of the 'genera' under consideration, and the matter was fully treated of in a paper. This paper, however, was not published, because it was considered a poor thing to put forward an idea having such a destructive tendency without providing an alternative scheme whereby a natural classification could be constructed. And the latter would involve much further detailed work, some of which has since been done.

Cumings,[2] however, in January of this year, in a paper on the development of *Fenestella* and other Palæozoic forms, has in a masterly manner shown that the zoarium has a developmental history, exactly comparable with that of the individual. He says:[3] "The now generally accepted classification of the stages of growth and decline, proposed by Alpheus Hyatt, has never been consistently applied to a colonial organism, such as are the Bryozoa, nor to one whose ontogeny presents the retrograde metamorphosis which characterizes the latter class." He further proposes a nomenclature for the stages in the development of the colony analogous to the nepionic, neanic, ephebic, and gerontic, or the infantile, youthful, mature, and old-age stages, proposed by Buckman & Bather[4] as modifications of Hyatt's original terms for the individual. These

[1] J. W. Gregory: Brit. Mus. Cat. Jur. Bryozoa, 1896, pp. 14–22.
[2] E. R. Cumings: Amer. Journ. Sci., vol. xvii, pp. 49–78.
[3] Cumings: op. cit., p. 50.
[4] S. S. Buckman & F. A. Bather, "The terms of Auxology": Zooglischer Anzeiger, 1892, p. 421.

colonial stages he terms nepiastic, neanastic, ephebastic, and gerontastic, formed from the stem of the first terms suffixed with the termination *-astic*, from τὸ ἄστυ, 'the city.'

Cumings also terms the first-formed zoarium, which has hitherto been known as the 'primitive disc' in Cyclostomata and the 'ancestrula' in Cheilostomata, the 'protœcium,' analogous to the 'protegulum' and 'protoconch' in Brachiopods and Ammonites respectively.

Among the Jurassic forms of *Stomatopora* and *Proboscina*, it has been found that when any given character, such, for instance, as the ratio of the length of the zoœcium to its breadth, is followed from the first zoœcium until the last, that it has a progressive development, or anagenesis, reaches a maximum or acme, and often may be seen to have a retrogressive development, or katagenesis, in the ultimate branches of the zoarium.

To illustrate this point, some examples of the character mentioned, namely, the ratio of the length of the zoœcium to its breadth, are given below, the points of dichotomy of the zoarium being taken as fixed points, and referred to by the numbers 1, 2, 3, etc., No. 1 being the point in the zoarium marked by the first dichotomy, and so on. The numbers with the names are the British Museum register numbers of the specimens.

Specimen.	Ratio of length of zoœcium compared with its breadth at the 1st, 2nd, 3rd . . . n^{th} dichotomies.						
	1	2	3	4	5	6	7
1. *Stomatopora Waltoni*, No. 97,083 ... ... Cornbrash, Wilts.	3½	4½	3	2¾	2¼	2¼	2
2. *Stomatopora dichotoma*, No. 60,535... ... Cornbrash, Wilts.	2½	2¾	3½	3	2¼	2	2
3. *Stomatopora dichotoma*, No. 46,218... ... Bathonian, Ranville.	1¼	1¼	1¾	1½	1¼	1¼	
4. *Stomatopora dichotoma*, No. B. 4,832 ... Cornbrash, Wilts.	2½	2½	2¾	2½	2	2	2
5. *Stomatopora*, sp. ... ... Cornbrash, Wilts.	2¾	3	2¼	2	2	2	
6. *Stomatopora Waltoni*, No. B. 2,287 ... Inf. Oolite, Gloucestershire.	2¾	2¾	2¼	2¼	2¼	2	2

The numbers in the above table, representing the length of the zoœcium (the breadth being taken as 1), are, of course, averages; for at each dichotomy are three zoœcia; and if n is the number of the dichotomy, the theoretical number of the zoœcia of which the average is taken will be $3\ (2^{n-1})$. Practically, however, the number is smaller, owing to the loss of certain branches.

The specimens whose zoœcial lengths are given in the table are chosen because they illustrate so well the regular changes of this character. Other specimens are more irregular, but all show to some extent a definite plan of development. In the first four cases given it will be seen that this character is anagenetic at first, and

reaches its acme at the third dichotomy, after which it is katagenetic. The fifth example reaches its acme at 2, while the sixth is at its acme at the first dichotomy, and declines after the second.

As far as actual length is concerned, numbers 2, 4, 5, and 6 are practically the same, while No. 1 has much longer and No. 3 much shorter zoœcia than the rest.

This particular character was chosen only as an example. Other characters show a similar regularity in development, according to the part of the zoarium in which they are situated. Those which have been observed and treated in the same way as the length of the zoœcium are four, two zoarial and two zoœcial. The zoarial are the method of branching, which will be treated later, and the frequency of branching, which is measured by the number of peristomes between two dichotomies. The zoœcial are the shape of the zoœcium, and its ornamentation by transverse ribs.

Two characters which have been used by former workers have been found by the author so unpractical that they have been given up as useless; these are the height of the peristome and the punctation of the zoœcium.

The first of these, though doubtless an excellent character where the state of preservation of the fossil is such that its presence may be counted on, becomes useless in the fossils here dealt with, because in the majority of cases the whole peristome has been broken off, leaving it impossible to say whether this structure was high or low when the organism was alive.

Again, the appearance of the punctation of the zoœcium seems to depend to such a large extent upon the state of preservation of the zoœcial wall, that its presence is of little use for systematic work. Nor does it appear to show any variation during the growth of the zoarium.

The results obtained from the study of the development of the characters previously mentioned, namely, the frequency of branching, the shape of the zoœcium, and the transverse ribbing of the zoœcium, show that the rule in the majority of cases is as follows:—

1. *Frequency of branching.*—The number of peristomes between the first two or three dichotomies is small (nearly always 1 or 2), then suddenly increases largely, and finally becomes small again.

2. *Shape of zoœcium.*—Generally the zoœcia are either cylindrical or pyriform. In many of those forms which have cylindrical zoœcia throughout the greater part of the zoarium, the zoœcia between the first and third dichotomies tend to be slightly pyriform; while in those forms with pyriform zoœcia, the zoœcia between the first and third dichotomies are generally more pyriform than the rest.

3. *Transverse ribbing of the zoœcium.*—Ribbing, when present, is usually faint at its first appearance, becoming stronger later on, and in some cases becoming fainter again finally. The point at which the acme is reached varies a great deal.

The systematic value of any one of these characters and the amount that the consideration of them affects the question of species

the author hopes to consider in a future paper; all that is wished at present is to demonstrate the importance of following each character through its own development in the zoarium, and by this means determining its value as an index to the relationship of one zoarium to another. The fact that each character has a developmental history makes it clear that the diagnosis of a form is incomplete, and for practical purposes useless, unless the part of the zoarium with respect to its age is specified.

The last point to be considered is the method of branching in the Jurassic forms of the two 'genera' *Stomatopora* and *Proboscina*.

In a single series of zoœcia, such as is typical in the genus *Stomatopora*, two ways of branching may be noticed, namely, lateral branching and dichotomy.

In lateral branching a new zoœcium arises from any point in a chain of old zoœcia, and generally diverges at a wide angle (see Diagram II, Fig. 1, p. 321). It is common in Silurian and Cretaceous forms, but has not been observed (except in one doubtful case) in any Jurassic form.

In dichotomy, which always occurs in Jurassic forms, two new zoœcia arise from the end of an older zoœcium, the angle at which they diverge varying from 180° to 20° or 30°, and varying in a definite manner. (See Diagram II, Figs. 2–9, p. 321.)

Dichotomy in the forms under consideration occurs in three types, one of which is intermediate between the other two. In that termed Type I the two new zoœcia are separate from one another throughout their whole length (Diagram II, Figs. 2, 3, 9, p. 321), only touching at their bases. In Type II they are contiguous throughout their length (Figs. 4, 5, 8); and they are contiguous for part of their length in the Intermediate Type (Figs. 5, 6, 7).

To a large extent correlated with the type of branching is the angle of divergence of the two new branches. This angle tends to diminish distally. But that it is not wholly dependent upon the type of branching may be seen in cases where the new branches diverge at an angle of as much as 60° after branching according to Type II (Fig. 5), while in other cases (Fig. 8) the two new branches may remain contiguous until they branch again. In the majority of cases, however, the angle of divergence and the type of branching are so closely correlated that for practical purposes they may be considered together.

Starting from the first zoœcium, which arises directly from the primitive disc, one or two zoœcia generally follow before the first dichotomy takes place. This in all *Stomatopora* and in a few *Proboscina* (e.g. *P. Cunningtoni*, Gregory, B.M. No. 23,852, zoarium marked 1) is after Type I with a wide angle nearly always 180° (Fig. 9). The second dichotomy in the great majority of cases is on Type I, with an angle of divergence of 120°. The angle of the next dichotomy is commonly 90°, of the next 60°, of the next 45°, Type I being still the mode of dichotomy.

In primitive forms (e.g. *S. Waltoni*, Haime, B.M. No. B. 2,287) the branching never gets beyond Type I with a small angle. In the

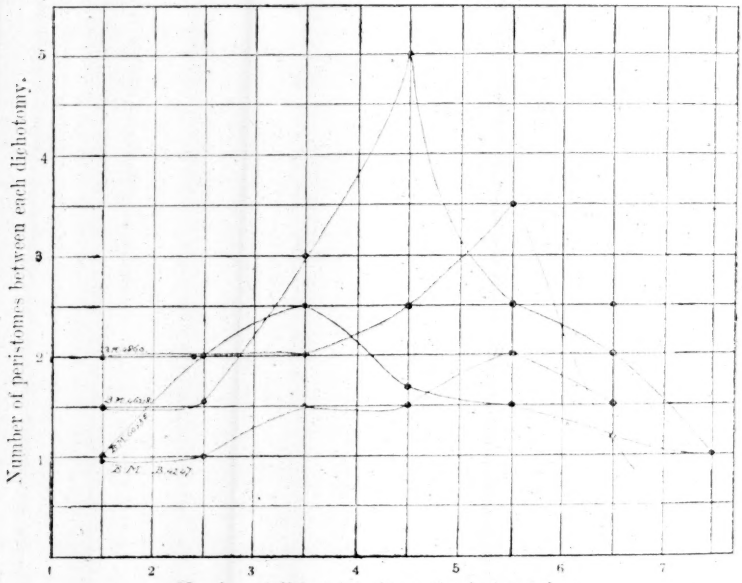
majority of forms, however, sooner or later the Intermediate Type of branching comes in, and in a great many forms this type is the final one. In a few cases of *Stomatopora*, and in all *Proboscina*, Type II is at some time or other reached, and remains the ultimate form of branching of the zoarium.

This sequence, namely, Type I—Intermediate Type—Type II, is invariably followed. For, although an individual dichotomy may occasionally occur of slightly more primitive order than its predecessor, it is only an irregularity, and the general scheme of development is in no wise obscured.

In more primitive forms this evolution in branching does not progress beyond Type I with a small angle.

In the commoner forms of *Stomatopora* the ultimate branches are formed on the Intermediate Type and on Type II.

Diagram I.—Curves showing the Frequency of Branching in Stomatopora.

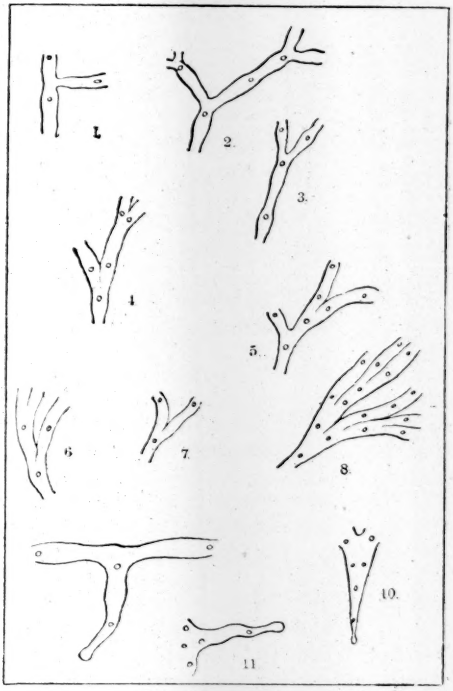


In a few forms of *Stomatopora* (e.g. B.M. No. B. 4,822) Type II occurs after a few dichotomies, while it comes in very soon in some primitive *Proboscina* (e.g. *Proboscina Cunningtoni*, Gregory, B.M. No. 97,617).

In typical forms of *Proboscina* the early stages have been so condensed, according to the law of acceleration (Tachygenesis),[1] that the first dichotomy is formed on Type II (Fig. 10). Sometimes

[1] A. Hyatt, "Bioplastology and the related branches of Biologic research": Proc. Boston Soc. Nat. Hist., vol. xxvi (1893), p. 77.

Diagram II, to show the method of branching in Jurassic forms of the two 'genera' *Stomatopora* and *Proboscina*.



These figures are diagrammatic reproductions of pieces of specimens in the British Museum. The Museum register number is given with each.

Fig. 1. Lateral branching; B. 4,238. *Stomatopora granulata* (Milne Edwards): Chalk, England; loc.? × about 5.

,, 2. Type I with large angle; B. 2,287. *Stomatopora Waltoni*, Haime: Inferior Oolite, Crickley Hill. Dichotomy 2. × about 4.

,, 3. Type I with small angle; B. 2,287, same specimen as the last. Dichotomy 8. × about 4.

,, 4. Type II with small angle; B. 4,247. *Stomatopora dichotomoides* (D'Orb.): Cornbrash, Wiltshire. × about 6.

,, 5. Type II with large angle, preceded by Intermediate Type with large angle; B. 4,832. Zoarium marked 2. *Stomatopora dichotoma* (Lamouroux): Cornbrash, Wiltshire. × about 6.

,, 6. Intermediate Type with small angle; B. 4,382, same specimen as the last, but the zoarium marked 1. × about 7.

,, 7. Intermediate Type with large angle; 60,536. *Stomatopora*, sp.: Cornbrash, Wiltshire. × about 6.

,, 8. Type II with an angle of 0°; 97,617. *Proboscina Cunningtoni*, Gregory: Cornbrash, Chippenham. × about 5.

,, 9. Type I with angle of 180°; D. 2,064. Zoarium marked 5. *Stomatopora dichotomoides* (D'Orb.): Cornbrash, Midland Railway Pit, Bedford. × about 13.

,, 10. The first dichotomy is after Type II with an angle of 0°; D. 7,185. *Proboscina*, sp.: Inferior Oolite, Crickley Hill. × about 7.

,, 11. The arrangement of the peristomes is irregular from the first; D. 1,843. *Proboscina Eudesi*, Haime: Inferior Oolite, Gloucestershire. × about 7.

a second dichotomy on Type II follows, but often the arrangement of peristomes is quite irregular after the first dichotomy.

In the most advanced types of *Proboscina*, e.g. *P. Eudesi*, Haime, B.M. No. D. 1,843, the arrangement of peristomes is irregular from the first (Fig. 11)—the arrangement typical for *Berenicea*, the next 'genus' in the series of which *Stomatopora* and *Proboscina* are the first two terms.

The absolute regularity of the sequence of these different types of branching and the condensation of the more primitive types in the more advanced forms show of how much importance this character is in determining the relationships of different forms. Moreover, it is worthy of notice that, while in the Jurassic forms of *Stomatopora* Type II is not very common, it becomes extremely common in the Cretaceous forms, though the sequence in these is considerably obscured by the superimposition of lateral branching upon the dichotomy.

In the case of the Cretaceous *Stomatopora* the lateral branching seems to be the reappearance of a character which was formerly present and has been lost, for it occurs in Silurian forms of *Stomatopora*, and is apparently absent in Jurassic forms.

Taking the type of branching as a character of primary importance, and following this and the other characters in their development from the beginning of the colony, series can be traced and natural relationships established. The true genera will probably be found to correspond to some extent with the present 'species.' But before this can be done at all satisfactorily it will be necessary to work through a great deal more material, carefully collected according to horizon and locality.

It is easy to represent graphically the evolution of the characters of two forms for comparison by means of curves. Diagram I, on p. 320, gives an example.

The writer of this paper, intending only to introduce his idea and method of dealing with this difficult group, as a means of establishing a natural classification, has purposely avoided entering into much detail, and confined himself rather to general statements. But illustrations are taken from actual specimens, and these may be seen in the British Museum. What is needed is more material which shall test the above propositions. What has been attempted is not arbitrarily to select a character and invest it with specific or generic importance, but by tracing the development of the character to assign it to its appropriate rank. The terms genus and species can then be applied with some meaning, and new forms, as they occur, will fall into their proper places in a natural scheme.

NOTICES OF MEMOIRS, ETC.

I.—The Geological Survey of England and important Coal-Developments in North Staffordshire.

LAST week the important announcement was made that the Dilhorne seam of coal had been recovered at the Klondyke pit No. 7, near Draycott Cross, Cheadle. For years sinking operations have been conducted with the object of winning what was known to be one of the most valuable seams of coal in the district, and considerable sums of money have been spent in the quest. It had always been held by old miners that although the Dilhorne seam did exist at Dilhorne, it did not exist in or about Cheadle proper. But from the inspection which was made of the Cheadle district about two years ago by Mr. George Barrow, F.G.S., of the Geological Survey, he came to the conclusion that the Dilhorne seam did exist at Cheadle, and that there was an area of some four square miles of it waiting to be worked.[1] This conclusion was borne out by Mr. Stobbs, the County Council lecturer in mining, from his examination of the fossils found in the strata overlying the coal-seams. In addition to these assurances, Mr. James Lockett, Chairman of the Cheadle Park Colliery Company, who has undertaken the researches that have at last proved successful, had the advantage of the observations which were made by his son, Mr. William Lockett, of the sections of strata which were penetrated by a borehole on the estate of the Cheadle Park Colliery, as well as in the Foxdale shaft and the Major Barn sinking, to assure him in his own conviction that the Dilhorne seam would be eventually won at the Draycott Colliery. Mr. Lockett commenced sinking from the Four-feet seam at the Draycott pit on January 1st this year. The difficult work of sinking through the water-bearing strata which lay beneath that seam has since been carried out efficiently, until on the 16th inst. the Dilhorne seam was reached, lying at a depth of 74 yards below the Four-feet seam and 150 yards from the surface, the seam at this point being about 5 ft. 1 in. thick and clean and bright. It is understood to be Mr. Lockett's intention to proceed with the opening out of the seam without delay, and it is expected that there will be an output from the Draycott Colliery within three years of a thousand tons a day. The land leased by Mr. Lockett amounts to 710 acres, owned partly by Sir Thomas Pilkington, Mr. F. Bolton, Oakamoor, and Mr. F. Mather, Betley, and if Mr. Barrow is right in his estimate there should be in the four square miles which comprise the Cheadle district a quantity of coal, taking the Four-feet and the Dilborne seams together, of from 20 to 25 million tons. In addition to this, there are two seams below the Dilhorne seam which have not yet been tapped. First, there is the 'cobble' vein, which is 2 feet thick, and then there is the Woodhead seam, 2 ft. 10 in. in thickness.

[1] [See "The Geology of the Cheadle Coalfield," by George Barrow, F.G.S., Mem. Geol. Survey, 1903, pp. 27, 28.—Edit. Geol. Mag.]

An encouraging feature about the new recovery is there is every indication of the seam being worked practically free from water. The coal is valuable for household purposes, and will be put upon all the principal markets, the pitbank being situated close beside the Cheadle Railway, to which sidings have already been laid down, and the colliery premises thus placed into communication within a very few miles of the North Staffordshire Railway Company's main line between Crewe and Derby.—*Colliery Guardian, May* 27, 1904.

II.—On the Ossiferous Cave-Deposits of Cyprus. By Dorothy M. A. Bate.[1]

PREVIOUS to 1901 no systematic search of the cave-deposits of Cyprus appears to have been attempted. The geology was studied by M. Albert Gaudry, who published an elaborate work in 1862 with a geological map, and Drs. Unger and Kotschy in 1865 also gave a geological map of the island, differing somewhat from their predecessor.

As long ago as 1700 the Dutch traveller Corneille le Brun (Van Bruyn) published an account of his wanderings in Cyprus and the Levant, and mentions having visited a bed of bones, supposed to be those of saints, not far from the Monastery of Haghios Chrysostomos. A drawing of one of these bones is given, which Dr. Forsyth Major has since shown to be that of *Hippopotamus minutus*.[2]

The author started in 1901 in expectation of discovering an extinct fauna in this ossiferous breccia, and this expectation was amply fulfilled, for no fewer than twelve ossiferous caves were found, five at Cape Pyla in the south-east and seven on the southern slopes of the Kerynia Hills in the north of the island.

Two caves (mentioned by General di Cesnola in 1877, at Cape Pyla, as containing *human* fossilised bones) were first visited by the author. The rock is here composed of Miocene (probably Helvetian) limestone, weathered to a very great extent, and full of marine shells and corals, as well as numerous Echinoids (*Clypeaster portentosus*), also met with in the Miocene limestones of Malta.

Here a number of caves were discovered in the cliffs, five of which yielded remains of *Hippopotamus minutus*.

The author then describes these caves in detail. The caves explored at Cape Pyla were: (1) The Red Cliff Cave; (2) the Great Anonymous Cave; (3) the Small Anonymous Cave; (4) Haghios Jannos; (5) Haghios Saronda. This is the cave to which formerly pilgrimages were made and candles burned in honour of the sacred remains of saints.

The cave-deposits of the Kerynia Hills are of uncertain geological age, no fossils having been obtained from the limestone rock of which they are chiefly composed. Professor Gaudry concludes that the rock is of Cretaceous age, and, therefore, the oldest sedimentary deposit in the island. The seven caves discovered were all on the

[1] Being the abstract of a paper read before the Royal Society, June 9th, 1904. Communicated by Dr. H. Woodward, F.R.S., F.G.S.

[2] Proc. Zool. Soc., June, 1902.

southern side of the range, between the Aghirdhir Pass and the village of Kythræa, in a low broken line of cliffs parallel with the main ridge. These are called the Kerynia caves, and are named—(1) Coutzaventis; (2) Haghios Chrysostomos; (3) Anoyero Spelios; (4) Dikomo Mandra; (5) Haghios Elias; (6) the Elephant Deposit; (7) the Western Cave.

Most of these caves have, by reason of long atmospheric erosion, partially or wholly disappeared, leaving the stalagmitic flooring containing mammalian remains unprotected and exposed often at a considerable distance from the face of the cliffs. But although many of them are now almost obliterated by the falling in of the roof and walls, the author points out that wherever this has happened the limits of the floor are sharply defined by the hard ossiferous deposit and the stalagmitic floor. In close proximity are caves still preserved containing precisely similar deposits.

The fauna of the caves is comparatively scanty, the only other important extinct form besides the dwarf elephant and hippopotamus being a new species of Genet (*Genetta plesictoides*), described in the Proceedings of the Zoological Society.

III.—Further Note on the Remains of *Elephas cypriotes*, Bate, from a Cave-Deposit in Cyprus. By Dorothy M. A. Bate.[1]

THIS paper is a continuation of one already published[2] "On the Discovery of a Pigmy Elephant in the Pleistocene of Cyprus," and enters into a detailed description of the teeth of this small proboscidean whose remains are now in the British Museum of Natural History.

The collection includes incisors, milk molars, and permanent molars. Several of the latter still retain their position in the jaws, and in some instances the teeth of both sides of the same individual were found.

The permanent incisor tusks of two forms, presumably belonging to males and females, were found. They differ from the same teeth of the Maltese dwarf elephants in being considerably compressed laterally. The largest specimen measures 29·7 cm. along the outside of the curve, with a maximum diameter of 3·7 cm.

Of the upper cheek teeth the third and fourth of the milk series, as well as the three permanent molars, are described in detail. There was a small third milk molar (mm. 2) implanted by a single root, but no specimen was collected.

Of the lower series, the third and fourth milk molars and the three permanent teeth were represented by numerous examples and are fully described.

An almost entire left ramus of one young individual and the symphysial portion of another are also described. The only limb bone obtained was the distal portion of a femur.

[1] Being the abstract of a paper read before the Royal Society, June 9th, 1904. Communicated by Dr. H. Woodward, F.R.S., F.G.S.

[2] Read before the Royal Society, May 7th, 1903; see Geol. Mag., 1903, p. 241.

A corrected ridge formula for the molars of *E. cypriotes* is furnished, which, exclusive of talons, will stand as follows :—

$$\frac{5}{5}, \frac{7-8}{7-8}, \frac{7-8}{7-8}, \frac{8-9}{8-9}, \frac{11-12}{11-12}$$

Dr. Leith Adams gives *E. melitensis* as follows :—

$$\frac{3}{3}, \frac{5}{5}, \frac{8-9}{8-9}, \frac{8-9}{8-9}, \frac{10}{10}, \frac{12}{12}$$

There appears to be a strong resemblance between the teeth of *E. cypriotes* and those of the Maltese and Sicilian pigmy forms, more especially *E. melitensis*, but the marked lateral compression of the tusks in *E. cypriotes*, which is a constant character in all the specimens so far obtained, would in itself be almost sufficient to distinguish this species from the other pigmy elephants of the Mediterranean region. There seems to be good evidence that *E. cypriotes* was isolated and subsequently differentiated at an earlier period than the other small Mediterranean species in Malta and Sicily, the zoological evidence giving considerable support to the belief that Cyprus became an island at an earlier period, an idea which is further strengthened by the fact that the whole island is surrounded by deep water, and is not connected with the neighbouring lands by submerged banks, as is the case with the Maltese Islands.

The Maltese pigmy species have been considered most closely allied to *E. antiquus* and *E. Africanus*. On the other hand, it seems probable that *E. cypriotes*, which shows no affinity to the African species, is connected rather with *E. antiquus* and *E. meridionalis*.

It may be remarked that the remains of *E. cypriotes* and of *Hippopotamus minutus*, with which it is associated, vary but little in size, whereas in the dwarf species of elephants and hippopotami from Malta and Sicily a considerable variation in size is observable, so much so indeed that molars may be seen intermediate in size connecting *H. melitensis* (=*minutus*), *H. pentlandi*, and *H. amphibius*.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—April 27th, 1904.—J. E. Marr, Sc.D., F.R.S., President, in the Chair. The following communications were read :—

1. "On a New Species of *Eoscorpius* from the Upper Carboniferous Rocks of Lancashire." By Walter Baldwin, Esq., F.G.S., and William Henry Sutcliffe, Esq., F.G.S.

The specimen described was found in an ironstone nodule occurring on a fairly well marked horizon, about 135 feet above the Royley Mine (or Arley Mine) coal-seam, at Sparth Bottoms, about half a mile south-west of Rochdale Town Hall. The nodules occur in a band of blue shale, in which are well-preserved remains of *Carbonicola acuta*, ferns *Calamaria*, *Prestwichia rotundata*, and *Bellinurus bellulus*.

The animal is well represented by both the intaglio and relievo impressions: these, however, only show its dorsal aspect. A description of the specimen is given, and it is referred to a new species. Dr. Peach is of opinion that, like the recent scorpions, the ancient species visited the sea-shore in search of the eggs of invertebrates left bare by the tides, and the association of this new scorpion with king-crabs at Sparth Bottoms is in favour of this view. The specimen has been presented to the Manchester Museum.

2. "The Genesis of the Gold Deposits of Barkerville (British Columbia) and the vicinity." By Austin J. R. Atkin, Esq. (Communicated by the Secretary.)

The gold-bearing area of Cariboo (British Columbia) is roughly confined within a radius of 20 miles of Barkerville, to the band of varied crystalline rocks known as the Cariboo Schists, generally assigned to the Lower Palæozoic group. The veins follow the strike but not the dip of the rocks, the gangue is similar to that associated with the nuggets in the placers, and the reefs show very little or no oxidized ore. While all the reefs carry gold in greater or less quantities, none have been found rich enough to account for the placer-gold. It is the opinion of the author that the placer-gold has probably been derived from the enriched outcrops of the veins which once existed above water-level. Such enrichment is due to two causes: firstly, the leaching-out of pyrites leaving the less soluble gold in lighter, honeycombed quartz; and, secondly, to actual enrichment by precipitation. This may be due to the solubility of gold in solutions of ferric sulphate, derived from the decomposition of the pyrites. While the enriched zone was being formed, the weathering of the surface kept removing the leached outcrop, and constantly exposing fresh surfaces to atmospheric influences. To the weathering of these outcrops the rich placers are attributed. Some of the nuggets in the latter show no signs of attrition, as though they had been carried to their present position enclosed in a soluble matrix which was afterwards removed. The denudation of the reefs and the deposition of gold in the gravels appear to have taken place in Tertiary times.

II.—May 11th, 1904.—Horace B. Woodward, Esq., F.R.S., Vice-President, in the Chair.

The Chairman referred in feeling terms to the grievous loss sustained by the Society in the death of Sir Clement Le Neve Foster, F.R.S., Professor of Mining at the Royal College of Science. He was elected a Fellow in 1863, and as early as 1865 he communicated to this Society, conjointly with William Topley, the now classic paper on the Medway Gravels and the Denudation of the Weald—a paper which had largely influenced the views of geologists on the physiography of the South-East of England.

The Chairman announced that the Council had resolved to award the proceeds of the Daniel-Pidgeon Fund for 1904 to Mr. Linsdall Richardson, F.G.S., of Cheltenham.

The following communications were read:—

1. "On some Quartzite Dykes in Mountain Limestone near Snelston (Derbyshire)." By Henry Howe Arnold-Bemrose, Esq., M.A., F.G.S.

At Snelston, $3\frac{1}{2}$ miles south-west by south of Ashbourne, there is an inlier of Mountain Limestone surrounded by Keuper Marl. It is roughly elliptical in shape, the major axis extending for a distance of about half a mile north-north-east and south-south-west.

The limestone is generally massive, with a few chert nodules in the upper parts; the rock in many places has a broken appearance, and it contains small hollow spaces; and large portions of the limestone have been partly or completely dolomitized. The floor and faces of the quarry are traversed by vertical veins or dykes of calcite, fluor-spar, barytes, calcareous sandstone, and quartzite.

The quartzite of these 'dykes' is described microscopically. It consists of angular detritus, quartz-grains with enclosures, a few small grains of felspar, and a few shreds of mica. The grains are cemented by silica, and sometimes by calcite. The rock in contact with the dykes sometimes contains quartz in isolated bipyramidal crystals and granular aggregates. The silica is present in the limestone in two forms, which have had an entirely different origin.

Reference is given to examples of sandstone dykes hitherto described, and then the origin of the quartzite dykes at this locality is discussed. An important bed of sandstone was found by sinking for a well at Marston Common Farm; and the same bed is found also in a quarry about 800 feet south of the farm. The microscopic aspect of the rock is precisely similar to that of the dykes. It is at a period later than the Keuper that the silica which cemented the sandstone of the dykes and of the Common Farm appears to have been introduced.

2. "Phenomena bearing upon the Age of the Lake of Geneva." By C. S. Du Riche Preller, M.A., Ph.D., A.M.I.C.E., M.I.E.E., F.R.S.E., F.G.S.

Following up his investigations concerning the age of the principal Alpine lake-basins, the author has, during a recent prolonged stay on the Lake of Geneva, examined the low-level gravel-beds and other alluvia to the Rhone Valley, from Geneva to the Jura bar near Fort de l'Écluse, as well as the high-level gravel-beds of La Côte above Rolle and of the Jorat district above Lausanne, and, further, the rock-formations on both sides of the lake, in view of evidence of flexures as the primary cause of the formation of the present deep lake-basin.

After describing the phenomena around the Lake of Geneva, and comparing them with those around the Lake of Zurich, he is led to the following conclusions:—

(1) The low-level gravel-beds of the Rhone Valley near Geneva are, like the deep-level gravel-beds of the Limmat Valley near Zurich, fluviatile deposits of the second interglacial period, and were formed before the present deep lake-basin came into existence.

(2) The high-level gravel-beds of La Côte above Rolle and of the Jorat district above Lausanne are, like the corresponding deposits of the Uetliberg near Zurich, and of the Dombes and of Lyons, true Deckenschotter. Hence the term 'alluvion ancienne,' should, in its proper acceptation, only apply to the high-level deposits.

(3) The formation of the present deep lake-basin of Geneva was, like that of Zurich, primarily due to the lowering of the valley-floor by flexures of the Molasse and its contact-zones, posterior to the maximum glaciation, as evidenced more especially by the reverse dip of the old erosion terraces.

The author holds that the concord of evidence in the two cases strengthens the conclusion, already arrived at by analogy in his previous paper, that the Lake of Geneva, together with the other principal zonal lakes between the Alps and the Jura, was formed under similar conditions and at the same time as the Lake of Zurich, that is, towards the close of the Glacial Period; indeed, the phenomena in support of that view are, in the case of the Lake of Geneva, on a grander scale, more striking, and, if anything, more conclusive.

III.—May 25th, 1904.—J. E. Marr, Sc.D., F.R.S., President, in the Chair. The following communications were read:—

1. "On the occurrence of a Limestone with Upper Gault Fossils at Barnwell, near Cambridge." By William George Fearnsides, Esq., M.A., F.G.S.

The section in the great Gault pit worked by the Cambridge Brick Company at Barnwell is as follows:—

	Thickness in feet.
5. Surface-soil with gravel and Chalk Marl, disturbed	15 to 17
4. Dull leaden clay, almost devoid of determinable fossils but with a few phosphate nodules, etc.	39
3. Compact, well-jointed, homogeneous clay, with large ammonites of the *rostratus*- or *Bouchardianus*-type ...	3
2. Hard calcareous bed with *Inoceramus*, *Schlœnbachia varicosa*, and *Terebratula biplicata*.....	0 to 1
1. Blue, well-laminated clay, with fossil fragments and pale phosphate nodules	4 seen

The limestone is variable in thickness, and is largely made up of comminuted shells of *Inoceramus*. It occurs in a series of flattened lenticles, a few yards in diameter and about a foot thick. It contains abundant phosphate nodules of at least three types—green, pale, and dark-brown in colour. Foraminifera are abundant, as also fragments of lamellibranchs, brachiopods, small gastropods, echinoids, and crustacea. A fibrous material, possibly chitin, chips of quartz, a little orthoclase, and glauconite are also recognized microscopically. The fauna is not markedly different from that of the underlying clay. A list is given which shows that this fauna has been recorded from the Upper Gault of Folkestone, and agrees most closely with that from Bed ix of Mr. Hilton Price's paper on that locality. As

these fossils are obtained 40 feet below the upper surface of the Gault seen in the section, it is clear that the whole of the Upper Gault of Cambridge was not used up in the making of the 'Cambridge Greensand'; and this fact, together with the northward thinning of the Gault as it passes into the Red Chalk, necessitates a modification in the view commonly held as to the origin of this 'Greensand' deposit.

2. "On the Age of the Llyn Padarn Dykes." By James Vincent Elsden, Esq., B.Sc., F.G.S.

The paper produces evidence which seems to suggest that the bulk of the greenstone dykes of this area belong to an earlier period of eruption than has been generally assigned to them; and there is proof that some of them may even be older than the quartz-felsite of the Llyn Padarn ridge. The greater part, if not actually of Bala age, seem to have been intruded before the great post-Bala crush-movements, which produced the folding of the Lower Cambrian rocks of Llanberis, had entirely ceased. At the same time, the evidence does not exclude the possibility that some of the intrusions may be of later date. The evidence on which these conclusions rest is based mainly on the signs which the intrusions exhibit of having been considerably modified by earth-pressures, more especially in those portions which protrude into Cambrian strata. Petrographical considerations, also, make it impossible to separate these rocks from the diabase sills of Bala age occurring farther to the south and south-west of this area; and there is a strong presumption that they represent the last residuum of the magma from which Bala sills were derived.

The north-western portions of the dykes, enclosed in the older rocks of the Llyn Padarn ridge, are comparatively free from dynamic metamorphism; but when traced into the more yielding Cambrian grits and slates, they become structurally deformed and often so highly sheared as to be hardly recognizable as parts of the same dyke. It is suggested that such highly sheared greenstones as occur in the ridge are of still older date. One section is described in which a sheared greenstone is pierced by a tongue of felsite about 2 inches wide and 2 feet long. The felsite is undistinguishable from that of the rest of the ridge and on the borders of the greenstone. Full petrographical descriptions of the minerals of the rocks in their altered and unaltered state are given, the minerals being taken in the order of their consolidation, and the rocks considered in the 'dynamic' or crush-zone of the sediments and in the 'static' or pressure-zone of the Llyn Padarn ridge. These minerals are apatite; iron-ores altered to sphene and leucoxene, and to a mineral which is apparently perowskite; felspars belonging to the albite-anorthite series of one generation undergoing 'albitization,' and the formation of felspar-mosaic; two pyroxenes, one possibly rhombic and the other like malacolite, granulitized and associated with secondary albite in the crush-zones, or passing into amphiboles and chlorites; original amphiboles rare, but common as actinolite, tremolite, and asbestos alteration-products

of pyroxene; biotite uncommon; chlorite; quartz; epidote; and calcite. In the least altered rocks the minerals are comparatively unchanged; then there is, first of all, molecular rearrangement under pressure without movement; next, mylonitization and recrystallization; and lastly, the whole rock becomes cataclastic, with partial or complete obliteration of its original structure. The gradual appearance of these features towards the east is proof that the deforming agency operated from that direction.

Mineralogical Society, June 7th, 1904.—Dr. Hugo Müller, President, in the Chair. The Rev. Mark Fletcher contributed a note on mispickel from Sulitjelma mine, Norway, containing about 1·32 per cent. of cobalt, and showing the forms [011], [012], [110]. —Mr. G. F. Herbert Smith exhibited a hand-refractometer of the Bertrand type in which the curvature of the focal surface has been reduced by means of a correcting lens, with a consequent improvement in the definition of the shadow edges.—Professor H. A. Miers gave an account, illustrated by numerous lantern slides, of the development of the Kimberley Diamond Mines. He traced the changes in the methods of working from the first surface diggings to the time when the blue-ground was brought to the edge of the pit by a 'cobweb' of wire ropes stretching from the numerous independent claims into which the mines were split up, and showed how the increasing difficulties involved in this method led to the final consolidation of the mines under Beit & Rhodes, and the initiation of the present system of mining, which consists in sinking shafts on the edge of the pit and running cross-cuts into the blue-ground. He referred finally to the recent discovery of blue-ground in the neighbourhood of Pretoria.

Palæontographical Society.

The annual general meeting of the Palæontographical Society was held at the Geological Society's apartments, Burlington House, on Friday, 17th June, Dr. Henry Woodward, F.R.S., President, in the Chair. The fifty-seventh annual report of the Council and the balance sheet were submitted for the approval of the members. The report began by alluding to the activity at present prevailing in the study of British fossils, and stated that the Palæontographical Society's Council continued to receive more offers of matter than they were able to accept for immediate publication. The volume for 1903 was unusually large, and was illustrated with no less than 48 plates. It comprised the concluding parts of Dr. Foord's Monograph of Irish Carboniferous Cephalopoda, and vol. i of Mr. Woods' Monograph of Cretaceous Lamellibranchia. It also contained instalments of the Monograph of Chalk Fishes, Carboniferous Lamellibranchiata, and British Graptolites, besides the first part of a new Monograph by Mr. Cowper Reed on the Palæozoic Trilobites of Girvan. The publication of this volume involved an expenditure of over £200 beyond the income received during the year. The report, indeed, showed a gradual decrease in the income of the Society during recent years, and referred to the necessity of filling

the numerous vacancies caused by death with the younger students of fossils, on whom the future prosperity of the Society depends. The loss of the Treasurer, Mr. Robert Etheridge, of Dr. C. H. Gatty, and of Mr. William Vicary, was especially deplored. Dr. Henry Woodward, F.R.S., was re-elected President; Dr. George J. Hinde, F.R.S., was elected Treasurer; and Dr. A. S. Woodward, F.R.S., was re-elected Secretary. Bishop Mitchinson, Rev. G. F. Whidborne, Mr. W. H. Hudleston, F.R.S., Mr. T. Leighton, and Mr. A. Strahan, F.R.S., were elected new members of Council.

CORRESPONDENCE.

THE 'YOREDALE' ROCKS OF NORTH DERBYSHIRE.

Sir,—A few days ago I enjoyed the privilege of attending the excursion of the Geologists' Association to North Derbyshire, and I was impressed by the tenacity with which many of the members of the party—including geologists of repute—adhered to the use of the term 'Yoredale' for the strata seen in the excavations of the Derwent Valley Water Board and elsewhere.

In Derbyshire and North Staffordshire there is a well-marked group, consisting of dark shales with thin limestones and sandstones, situated above the massive Mountain Limestone and below the lowest of the Millstone Grits.

I should like to ask those who still consider the name 'Yoredale' to be applicable to this group in this area to be so kind as to state the foundations of their belief. Are the palæontological or the lithological characters their guide?

From either point of view, I think it has been clearly shown that the deposits in question are sufficiently differentiated from the typical Yoredales to justify a distinctive appellation.

The name 'Yoredale' is a good one so long as it is confined to the type of deposit that exists in and about the Yorkshire Yoredale district; in addition to its historic interest it has an intrinsic value in connoting a set of conditions pre-eminent in that area; but to continue to use it for this rock in North Staffordshire and Derbyshire is to maintain a stumbling-block in the way of all workers who are not familiar with the two areas.

The name 'Pendleside Group' has been proposed by Dr. Wheelton Hind and myself, but if there are objections to this there still remains the choice of the non-committal 'Shales with limestones' and 'Shales with sandstones' of the Geological Survey.

Call them what you will; but if the name Yoredale is to stand for these beds let it be on the basis of solid palæontological evidence.

Museum of Practical Geology, London. J. Allen Howe.
May 28th, 1904.

NEOLITHIC FLINT FLAKES AT HOPE'S NOSE, TORBAY.

Sir,—On the 4th of last May I found four flakes or chips of flint about two feet deep in the earthy head or landwash capping the low cliff on the eastern side of the raised beach at Hope's Nose. The

fragments were exposed on the face of the section. Sir John Evans kindly informed me that he considered two of the flints to be artificially made, and probably of Neolithic date. The soft earthy capping of the cliff is about the same height as the highest beach deposits, but is clearly much more recent. The flints did not overlie the beach, but were to the eastward of the eastern end of the raised beach.

I see that Sir Archibald Geikie mentions the fact that the 20 foot terrace on the north-east coast of Ireland has *produced* many worked flints, regarded as Neolithic (Q.J.G.S., vol. lx, p. xcvi). These Hope's Nose flints are clearly more recent than the raised beach (about equivalent to a 24 foot terrace), and it is likely enough that they were made out of the flints which occur in the beach, but are not elsewhere found in the immediate neighbourhood. I am far from wishing to trouble your readers with any remarks of my own on this rather perplexing subject, but the mere fact of the discovery of Neolithic flakes newer than the adjacent beach at Hope's Nose, Torbay, may be worth a bare record. A. R. Hunt.

Southwood, Torquay.
June 14th, 1904.

OBITUARY.

FRANK RUTLEY.

Born May 14, 1842. Died May 16, 1904.

The son of a medical practitioner at Dover, Frank Rutley became early in life interested in geology, and studied at the Royal School of Mines from 1862 to 1864. In 1867 he was appointed an Assistant Geologist on the Geological Survey, under Sir Roderick Murchison and Professor Ramsay. For a few years he was engaged in field-work with W. T. Aveline in the Lake District. There he gave some attention to the subject of glaciation, but, probably through the influence of his colleague, the late J. Clifton Ward, he began to undertake the special study of rocks and rock-forming minerals. The importance of the microscope in the examination of rocks was at this period becoming recognized, and Mr. Rutley was transferred to the Geological Survey Office in Jermyn Street, to undertake the determination and description of the igneous rocks that were collected in the course of the geological survey; he took charge also of the rock-collection in the Museum of Practical Geology. His first official work dealt with the volcanic rocks of East Somerset and the Bristol district (1876), and he later on wrote special memoirs on the eruptive rocks of Brent Tor (1878), and on the Felsitic Lavas of England and Wales (1885).

He was author in 1874 of a small but exceedingly useful work on Mineralogy for Murby's "Science and Art Department" series of text-books, of which a twelfth edition was issued in 1900. In 1879 he wrote an elementary text-book of Petrology, the first work of the kind published in this country, entitled "The Study of Rocks,"

and illustrated by many of his own excellent drawings. Of this a second edition was issued in 1881. Later on in 1888 he published a work on "Rock-forming Minerals," and in 1894 "Granites and Greenstones: A series of Tables and Notes for Students of Petrology."

In 1882 Mr. Rutley was appointed Lecturer on Mineralogy in the Royal College of Science, a post which he occupied for about ten years, when he was unfortunately forced to retire through disablement by paralysis. For several years, so far as his strength permitted, he continued to work with unabated enthusiasm at petrological subjects; and until the end he never ceased to take great interest in his favourite studies. He was a man who in early life was endowed with great vigour, but his habits were somewhat erratic; he burned the midnight oil far too much, toiling into the early morning when he should have slumbered, and finding it difficult in consequence to conform to the regulations of official life; but he was a genial companion, full of dry humour, and ever ready to assist others. His published work shows how assiduous and painstaking he was, and the accompanying list gives the best idea of the special researches which he carried on for a number of years. He was awarded the Murchison Fund by the Council of the Geological Society in 1881, and later on he served for a few years as a member of the Council:—

1865. [Letter on a Subsidence at Lexden, in Essex]: Geol. Mag., Vol. II, pp. 231–2.
1870. [Letter on] Geology of the Lake District: ibid., Vol. VII, pp. 584–5.
1871. [Letter on] Glaciation of the Lake District: ibid., Vol. VIII, p. 93.
1873. "On a New Method of Writing Crystallographic Formulæ": ibid., Vol. X, pp. 299–301, 527–8.
1875. "Notes on some peculiarities in the Microscopic Structure of Felspars": Quart. Journ. Geol. Soc., vol. xxxi, pp. 479–487.
1876. "On some Structures in Obsidian, Perlite, and Leucite": Micr. Journ., vol. xv, pp. 176–183.
1877. "On Microscopic Structures in Tachylite from Slieve-nalargy, Co. Down, Ireland": Journ. Roy. Geol. Soc. Ireland, ser. II, vol. iv, pp. 227–232.
1879. "On Community of Structure in Rocks of Dissimilar Origin": Quart. Journ. Geol. Soc., vol. xxxv, pp. 327–340.
"On Perlitic and Spherulitic Structures in the Lavas of the Glyder Fawr, North Wales": ibid., pp. 508–9.
1880. "On the Schistose Volcanic Rocks occurring on the West of Dartmoor, with some Notes on the Structure of the Brent Tor Volcano": ibid., vol. xxxvi, pp. 285–294.
[Letter on] The term 'Schist': Geol. Mag., Dec. II, Vol. VII, pp. 239–40.
1881. "The Microscopic Characters of the Vitreous Rocks of Montana, U.S.A.": Quart. Journ. Geol. Soc., vol. xxxvii, pp. 391–399.
"On the Microscopic Structure of Devitrified Rocks from Beddgelert and Snowdon; with an Appendix on the Eruptive Rocks of Skomer Island": ibid., pp. 403–412.
"Visit to the Museum of Practical Geology [Rock Collection]": Proc. Geol. Assoc., vol. vii, pp. 114–15.
1884. "On Strain in Connexion with Crystallization and the Development of Perlitic Structure": Quart. Journ. Geol. Soc., vol. xl, pp. 340–346.
1885. "On Fulgurite from Mont Blanc; with a Note on the Bouteillenstein, or Pseudo-Chrysolite of Moldauthein, in Bohemia": ibid., vol. xli, pp. 152–156.
"On Brecciated Porfido-rosso antico": ibid., pp. 157–161.
[Letter on] The Enstatitic Lavas of Eycott Hill: Geol. Mag., Dec. III, Vol. II, p. 285.

1886. "On some Eruptive Rocks from the Neighbourhood of St. Minver, Cornwall": Quart. Journ. Geol. Soc., vol. xlii, pp. 392–400.
"The Igneous Rocks, etc., of the Neighbourhood of the Warwickshire Coal-field": Geol. Mag., Dec. III, Vol. III, pp. 557–565.
1887. "On the Rocks of the Malvern Hills": Quart. Journ. Geol. Soc., vol. xliii, pp. 481–514.
1888. "On Perlitic Felsites, probably of Archæan Age, from the Flanks of the Herefordshire Beacon; and on the possible Origin of some Epidosites": ibid., vol. xliv, pp. 740–744.
1889. "On Fulgurites from Monte Viso": ibid., vol. xlv, pp. 60–66.
"On Tachylite from Victoria Park, Whiteinch, near Glasgow": ibid., pp. 626–632.
1890. "On Composite Spherulites in Obsidian from Hot Springs near Little Lake, California": ibid., vol. xlvi, pp. 423–428.
"On a Specimen of Banded Serpentine from the Lizard, Cornwall": Trans. Roy. Geol. Soc. Cornwall, vol. xi, p. 239.
[Notes on Anglesey Rocks]: Proc. Liverpool Geol. Soc., vol. vi, p. 2.
1891. "On a Spherulitic and Perlitic Obsidian from Pilas, Jalisco, Mexico": Quart. Journ. Geol. Soc., vol. xlvii, pp. 530–532.
"On some of the Melaphyres of Caradoc, with Notes on the Associated Felsites": ibid., pp. 534–543.
"Notes on Crystallites": Min. Mag., vol. ix, p. 261.
1892. "Note on Crystals of Manganite from Harzgerode": ibid., vol. x, pp. 20–1.
1893. "On the Dwindling and Disappearance of Limestones": Quart. Journ. Geol. Soc., vol. xlix, pp. 372–382.
1894. "On the Sequence of Perlitic and Spherulitic Structures: a Rejoinder to Criticism": ibid., vol. l, pp. 10–13.
"On the Origin of certain Novaculites and Quartzites": ibid., pp. 377–391.
"Note on a Zircon from Expailly, Haute Loire": Min. Mag., vol. x, p. 278.
"On Fulgurites from Griqualand West": ibid, p. 280.
"Note on some Inclusions in Quartz": ibid., p. 285.
1895. "On a Sandy Ironstone occurring above the Chalk at Capel, near Dover": Geol. Mag., Dec. IV, Vol. II, pp. 227–229.
1896. "On the Alteration of certain Basic Eruptive Rocks from Brent Tor, Devon" (abstract): Quart. Journ. Geol. Soc., vol. lii, p. 66.
1899. "On a Small Section of Felsitic Lavas and Tuffs near Conway (Caernarvonshire)": ibid., vol. lv, pp. 170–175.
(With J. Park.) "Notes on the Rhyolites of the Hauraki Goldfields (New Zealand)": ibid., pp. 449–468.
1900. "Additional Notes on some Eruptive Rocks from New Zealand": ibid., vol. lvi, pp. 493–510.
1901. "On some Tufaceous Rhyolitic Rocks from Dufton Pike (Westmorland)": ibid., vol. lvii, pp. 31–37.
[Note] "On the Olifant Klip from Lydenburg and Ladysmith": Geol. Mag., Dec. IV, Vol. VIII, p. 555.
1902. "On an Altered Siliceous Sinter from Builth (Brecknockshire)": Quart. Journ. Geol. Soc., vol. lviii, pp. 28–34.

MISCELLANEOUS.

Bridlington Crag.—The fauna of the Bridlington Crag, described by Mr. G. W. Lamplugh in the Geological Magazine for 1881, has always been of special interest to geologists.[1] The following account by Mr. Thomas Sheppard of recent excavations at Bridlington exposing this deposit will be of special interest to our readers.

Recently an opportunity has presented itself of examining the shell patches, and a party of geologists left Hull for an examination

[1] See also his letter in May No., p. 237.

of the excavations now being carried on in connection with the new sea-wall and promenade being built at Bridlington. For the purpose of making secure foundations, large square holes of about 8 feet sides are dug into the beach at some distance from the present sea-wall, north of the promenade. These excavations are made to extend about 6½ feet into the basement clay—the dark, leaden-coloured, compact deposit containing foreign stones and occasional shell fragments. At irregular intervals in the clay occur pockets or streaks of the 'Crag,' which are not welcomed so much by the contractors as by the geologists. These pockets sometimes consist of a slightly greenish-coloured sand, crowded with shell fragments, and in other cases the sand is of a ferruginous nature, due to a quantity of iron oxide. Whilst shells usually occur in profusion in these pockets, their condition, number, and variety differ. In one the shells are found to be broken up into very small fragments; in another they occur not so plentifully, but in fairly perfect condition; another will principally contain portions of one particular species, such as *Cyprina islandica*. Another contained several large *Pectunculi*.

Mr. Matthews, the borough surveyor of Bridlington, who has interested himself in the matter, has done his best to assist the local geologists, and a fine collection which he has got together has been presented to the Hull Museum, through Mr. Stather, the Secretary of the Hull Geological Society. Amongst the material is a small heap of broken shell fragments, some far-travelled pebbles (an examination of which will doubtless yield interesting results), a few fairly perfect shells, and a single tooth of probably a small shark. These represent the careful washing of two bucketfuls of material. In addition Mr. Matthews kindly conducted the visitors round the excavations, where, fortunately, much of the shell material had recently been thrown out, and from this many fairly perfect specimens were obtained, and a large quantity of the shell-bearing sand was brought away for detailed examination. Among the shells secured the following have been identified, and many more will be added to this list after the material has been properly examined: *Anomia ephippium*, *Pecten islandicus*, *Mytilus edulis*, *Nucula cobboldiæ*, *Pectunculus glycymeris*, *Cardium*, *Cyprina islandica*, *Astarte compressa*, *Tellina balthica*, *Mactra*, *Mya*, *Saxicava rugosa*, *Pholas*, *Dentalium entales*, *Scalaria*, *Fusus*, and *Pleurotoma*.

The collection made by the late Judge Bedwell, together with those recently acquired, will be exhibited in a case in the Museum. [*Hull Mus. Publ.*, *No.* 19, 1904.]

Professor E. Kinch, of Cirencester, discusses the question of "The Thames Head" (*Agricultural Students' Gazette*, April, 1904), and maintains that the true head is at Trewsbury Mead, Coates, near Cirencester.

"Notes on the Glacial Phenomena of part of Wharfedale" form the subject of an article by Mr. J. R. Dakyns (Proc. Yorksh. Geol. and Polytech. Soc., vol. xv, pt. 1). He finds no evidence of foreign ice, but all the facts indicate huge confluent glaciers, or ice-shafts (if that term is preferred) of home-made ice.

SUPPLEMENT TO THE

GEOLOGICAL MAGAZINE

FOR JULY, 1904.

ON THE ORIGIN OF THE MARINE (HALOLIMNIC) FAUNA OF LAKE TANGANYIKA.

By W. H. Hudleston, M.A., F.R.S.

(*Vice-President, Victoria Institute.*)

[*With Two Plates.*]

A Paper read before a Meeting of the Members and Associates of the Victoria Institute, on May 25th, 1904, and published in this Magazine, by kind permission of the Council, in advance of the annual volume of their Transactions for 1904.

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NOTE.—It should be observed that the title of this paper is rather unfortunate since it starts by begging the question of a marine origin. I consented to write a paper for the *Victoria Institute* on the "Tanganyika Problem," and this I have endeavoured to do, so far as available information will allow me, but I admit at the outset that many years of observation must elapse ere the Tanganyika Problem is fully solved.

PART I.

GENERAL CONSIDERATIONS, ZOOLOGY AND PALÆONTOLOGY.

Introductory.—Fifty years ago Central Africa itself presented a problem, which as far as geographical exploration extends, was ripening for solution at the hands of the bold explorers of the latter half of the nineteenth century. By degrees the wonders of the Dark Continent were revealed to the geographer and the naturalist, and even the geology of those regions has received some share of attention, rather by way of comparison with the already known features of more accessible districts, such as the Cape, than for any detailed and systematic description of the rocks which constitute their surface. Although missionaries of German origin contributed materially to our early knowledge of East Central Africa, still the larger share of exploration has fallen to the lot of our own fellow-countrymen.*

When the geographical features became better known, it was ascertained that this once mysterious region contained numerous lakes of immense size, some of them situated in deep chasms of the earth's crust. And, more unexpected still, it was found that there were volcanoes both extinct and active, constituting lofty mountains; and furthermore that on some of these mountains glaciation had been developed on a considerable scale, and that glaciers even now exist on the higher peaks, actually under the equator.

What wonder, then, that Equatorial Africa, and particularly the eastern portion of it, should present problems, both in geology and zoology, which are difficult of solution? As for ourselves we must admit at the outset that we are entirely dependent on the descriptive portion of those numerous and excellent works, which tell us of this country; and if we venture in any case to hesitate at accepting all the inferences

* One of the greatest of whom, Sir H. M. Stanley, has just passed away; to the general regret of all from the King downwards. Sir Henry Stanley was a Hon. Corresponding Member of the Institute.—E. H. (ED.)

which their authors have drawn, it must be with bated breath and with the full consciousness ever present in our minds that they have been there and that we have not. In the light of so much that has recently been revealed, it is only natural that many controversies should arise and some of these perhaps may be ultimately settled by more extended investigations leading to further knowledge of the subject. As a case in point, I may mention the remarkable circumstance which has greatly exercised the minds of certain zoologists, viz.:—that there are some species of fishes in the waters of the Upper Nile which also occur in the hydrographic basin of the Jordan in Palestine, and yet are not found in the waters of the Lower Nile in Egypt. When zoologists are desirous of accounting for anything which seems abnormal or difficult of explanation, they are quite prepared to make the earth's surface undergo considerable modifications in order to suit their special line of argument, and indeed they can generally find a sufficient number of geologists to back them in such a course. This subject may crop up again when we proceed to consider the geological structure of eastern Equatorial Africa, and, therefore, it will be sufficient at the present moment merely to refer to the hypothesis, which connects the drainage of the Jordan system, through the Gulf of Akabah and the valley of the Red Sea, then supposed to be a fresh-water river, with a portion of the "Rift Valley" system, and ultimately with the drainage of the Upper Nile. Far be it from me to say that such an explanation is incorrect, but it certainly ignores all existing hydrographic arrangements most completely.*

The case I have just quoted is perhaps more difficult of solution than the problem which we are now called upon more especially to consider, viz.:—the origin of the halolimnic fauna of Lake Tanganyika, or in other words what Mr. Moore very aptly calls the "Tanganyika Problem." In attempting to grapple with this very curious and interesting question, besides the zoological evidence, it will be necessary to consider the geological structure of Equatorial Africa as far as the scanty details of our present knowledge permit; and if we venture in this connection to attempt to trace any portion of its physical history in times past, such reconstruction should harmonize as much as possible with known facts and existing features.

* On this subject the reader is referred to a paper "On the physical conditions of the Mediterranean Basin, which have given rise to a community of some species of fresh-water species in the Nile and in the Jordan Basins." *Trans. Vict. Inst.*, vol. xxxi, p. 3 (with map).—E. H. (Ed.)

History of the subject and statement of Mr. Moore's views.—The history of the recognition of the halolimnic fauna is important as tending to show what were men's views from time to time as each step in the progress of discovery was made. It will be remembered that Lake Tanganyika was discovered by Burton in 1857, and that his companion, Speke, picked up a few dead shells from the shores and brought them to England. The well-known conchologist, Dr. Sam. P. Woodward (*Proc. Zool. Soc.*, 1859, p. 348, Pl. XLVII) was struck with the peculiar forms of some of the gasteropods, which he considered had a certain marine look about them. Subsequently when further supplies were procured, Mr. Edgar Smith (*Proc. Zool. Soc.*, 1881, p. 276), in a paper on a collection of shells from Lakes Tanganyika and Nyassa, expressed an opinion that they might turn out to be the relics of a former sea. The subsequent discovery of medusæ in Lake Tanganyika seemed to confirm these views as far as that lake was concerned. Hence before Mr. Moore appeared upon the scene most of those who had paid attention to the subject had expressed themselves as favouring the view of the marine origin of this peculiar fauna.

Mr. Moore, as a result of his first journey in 1896, found "that in Nyassa and Shirwa there were no jelly-fishes, nor anything except purely fresh-water forms: while in Tanganyika there were not only jelly-fishes, but a whole series of molluscs, crabs, prawns, sponges, and smaller things, none of which appeared in any of the lakes he then knew, and all of which were distinctly marine in type.* Further than this, however, he found that none of these strange marine looking animals were to be compared directly with any living marine forms, yet, in their structure, some of them certainly seemed to antecede a number of marine types in the evolutionary series, and, in consequence, they appeared to hail from the marine fauna of a departed age. The most definite result of the first Tanganyika expedition, therefore, appeared to be that the sea had at some former time been connected with the lake, but when or how remained a mystery."

The above are Mr. Moore's own words in explanation of his views after the termination of his first expedition. It should be borne in mind that at this period, viz., in 1898, when his inferences were laid before the Royal Society (*Proc. Roy. Soc.*, vol. 62), there was an idea then partially and perhaps generally prevailing, that owing to the peculiar structure of the Rift-

* J. E. S. Moore, *The Tanganyika Problem* (1903), p. 3.

Valley system and its obvious physical connection with the great Red Sea depression, that the "halolimnic" fauna might have entered Lake Tanganyika from that quarter, and would consequently be found in some of the Rift-Valley lakes to the northwards, and especially in Lake Kivu, with which at the present day Tanganyika is hydrographically connected through the River Rusizi. It was therefore indeed a surprise when Mr. Moore had to announce as the result of his second expedition, commenced in the spring of 1899, that no trace of the "halolimnic" fauna had been discovered in any of the lakes, such as Kivu, the Albert Edward, or the Albert Nyanza, which lie to the northward of Tanganyika in the western arm of the Rift-Valley system. Nay, more, it would seem that no such thing as the halolimnic fauna was to be found in the great upland basin of the Victoria Nyanza, nor in the chain of lakes associated with Lake Rudolf (Basso Narok), which lie towards the northern termination of the eastern arm of the Rift-Valley system.*

To quote Mr. Moore's own conclusions on this point: "It has been shown that throughout Equatorial Africa, as in other great continents, there is a normal fresh-water fauna which has nothing peculiar about it . . . Subsequently, the fauna of L.

* There appears to be no longer any doubt as to the presence in Lake Victoria Nyanza of medusæ indistinguishable from those of Lake Tanganyika, and the fact cannot be without its effect upon the acceptance of the view put forward by Mr. J. E. S. Moore that the fauna of Lake Tanganyika differs from that of the other East African lakes in alone possessing evidences of a marine origin. On December 1, 1903, Prof. Ray Lankester exhibited at the Zoological Society some medusæ from Victoria Nyanza obtained by Mr. Hobley on August 31, 1903, and sent to London by Sir Charles Eliot. A doubt being raised by some supporters of Mr. Moore's theory as to these medusæ having really come from Lake Victoria and not from Lake Tanganyika, Sir Charles Eliot, in a letter dated Mombasa, December 20, 1903, wrote to Prof. Lankester saying that the medusæ were collected by Mr. Hobley himself, in the Kavirondo Gulf, by the side of which the railway terminus is situated, and that the water was full of them. Mr. Hobley, at the request of Sir Charles Eliot, had endeavoured to study the life-history of the medusæ, but he failed to keep them alive for more than a few days. The specimens sent to London were said by Mr. R. T. Günther to be indistinguishable from the *Limnocnida tanganyicae* of Lake Tanganyika. It is interesting in this connection to note that the Victoria medusæ were discovered quite independently in the same locality (Kavirondo, in the Kisuma district), and apparently at about the same time of year. According to *Globus* (January 28, p. 84), M. Ch. Alluaud, on the day of his arrival at Lake Victoria, discovered a marine medusa similar to that of Lake Tanganyika, and communicated an account of his discovery to the Paris Geographical Society on September 19, 1903.—*Nature.*

Tanganyika has been examined in detail, and it has been shown that this lake, like all other great lakes of Central Africa, contains the ordinary fresh-water fauna of the continent; but that in Tanganyika, and in Tanganyika alone, there are a number of organisms possessing definitely marine and somewhat archaic characters. Along with these, the halolimnic members of the Tanganyika fauna, there are others, such as the prawns, sponges and protozoa which, although not like the previous types, unique in being found in Tanganyika for the first time as fresh-water forms, are notwithstanding probably portions of the same group, for they are peculiar to Tanganyika, and are not characteristic of the general fresh-water fauna of the African continent." He further suggests that the African ganoids and certain other members of the African fish fauna may be portions of the "halolimnic" fauna. Lastly, he points to the significance of the similarity which subsists between the shells of the halolimnic gasteropods and "the remains of those found in the deposits of the old Jurassic seas."

Thus far Mr. Moore. When we ourselves attempt to face the Tanganyika Problem, it is obvious that it will have to be considered both from a zoological and a geological point of view, and the question is which shall we consider first, the zoology or the geology? We are dealing with an exceptional fauna, occurring under peculiar conditions and in what was, until quite recently, a most out-of-the-way place. Perhaps the first question we should ask ourselves is this: Do we consider that there is sufficient evidence of the marine origin of the halolimnic fauna? This fauna is placed by Mr. Moore himself under two different categories. (1) The halolimnic gasteropods, which are thought to be homæomorphic with certain shells from beds of the Inferior Oolite formation in Western Europe, and are thus inferentially regarded as descendants of those forms. (2) A fauna, not so thoroughly exceptional as the halolimnic gasteropods, made up of prawns, sponges, protozoa, etc., which are archaic in type and may be portions of the same group of marine derivatives. The presence of *Medusa* also is held greatly to strengthen this view. As regards the portion of the argument relating to the fishes it has been stated by a competent authority that the fishes described by Mr. Boulenger in Mr. Moore's beautiful book are all essentially present day types, and do not in any way represent survivors from the seas of the Mesozoic period.*

* *Geological Magazine*, September, 1903, p. 418.

The argument limited to the halolimnic gasteropods.—Although, therefore, the subsidiary fauna of exceptional character may help to strengthen the argument in favour of the marine origin of the entire halolimnic group, yet the most important link in this chain of evidence is to be sought in the *halolimnic gasteropods*, which are considered so greatly to resemble Inferior Oolite forms, and which on the strength of this resemblance are held to be derived from a well known gasteropod fauna of Jurassic age. The malacological evidence, as regards the Tanganyika species, has been well worked out by Mr. Moore, and the conclusions as to the peculiar mixed and to a certain extent archaic structure of their anatomy must undoubtedly have great weight. But at this point the argument fails us, for when we are disposed to institute a comparison between living and fossil species we must in the main fall back on conchology alone. One point of importance must be noted here, viz., that, since the connection between the halolimnic fauna of Tanganyika and the old Jurassic marine fauna is confined to univalves, one might almost have expected that some lamellibranchs, and particularly *Trigonia*, if only in a modified form, might have accompanied their molluscan relatives. For it can hardly be contended that *Trigonia* would suffer more from translation to fresh-water conditions than the numerous species of gasteropods which are correlated with Jurassic forms. Moreover, if conchology is to be our guide in this matter, it is to be regretted that the author of the "Tanganyika Problem" should have endeavoured to minimize the value of a branch of science on which his conclusions with reference to the Jurassic origin of these Tanganyika shells must in the main be based.*

The above considerations apart, it must be admitted that there are some genera of Tanganyika gasteropods which have a striking external resemblance of form and ornamentation to certain well-known genera which more especially characterize the Inferior Oolite of the Anglo-Norman basin; and if such resemblance is not fortuitous there seems a fair reason for regarding them as the possible descendants of such genera or their allies. Consequently, some portions of Mr. Moore's latest work are devoted to a detailed comparison between the Tanganyika shells and their presumed Jurassic analogues. The text is accompanied by excellent illustrations, the shell and the fossil being drawn side by side. As a detailed criticism of these comparisons might be somewhat tedious to the members

* *Geographical Journal* for 1903, p. 682 *et seq.*

of this Society, it will be sufficient to relegate this portion of my paper to an appendix, and briefly to state the impressions which a careful examination of both sets of shells, the fossil and the modern, have left upon my mind.*

As a result of this detailed examination I find on conchological grounds, that the evidence of an ancestral connection between certain fossils of the Inferior Oolite of the Anglo-Norman basin and the following halolimnic genera, viz., *Typhobia*, *Bathanalia*, *Limnotrochus*, *Chytra*, *Paramelania*, *Bythoceras*, *Tanganyicia*, *Spekia*, and *Nassopsis*, is not nearly so strong as I had anticipated from the inferences already drawn and from what I had read in several publications. There are two Jurassic genera, chiefly developed in the Lower Oolites, viz., *Amberleya* and *Purpurina*, which have their conchological analogues in Lake Tanganyika, and in some cases the resemblance is very striking. But this is scarcely sufficient to justify the assumption that the oceanic character of these Tanganyika molluscs will more or less necessitate that the Tanganyika region of to-day must have approximated in character to an arm of the deep and open sea in ancient times,† and the inference is in Jurassic times. Indeed some people, I believe, have gone so far as to describe Tanganyika as an arm of the Jurassic sea. On biological grounds alone this is not at all probable; because under any circumstances this would have been a different zoological province from that occupied by the Anglo-Norman basin in Jurassic times.

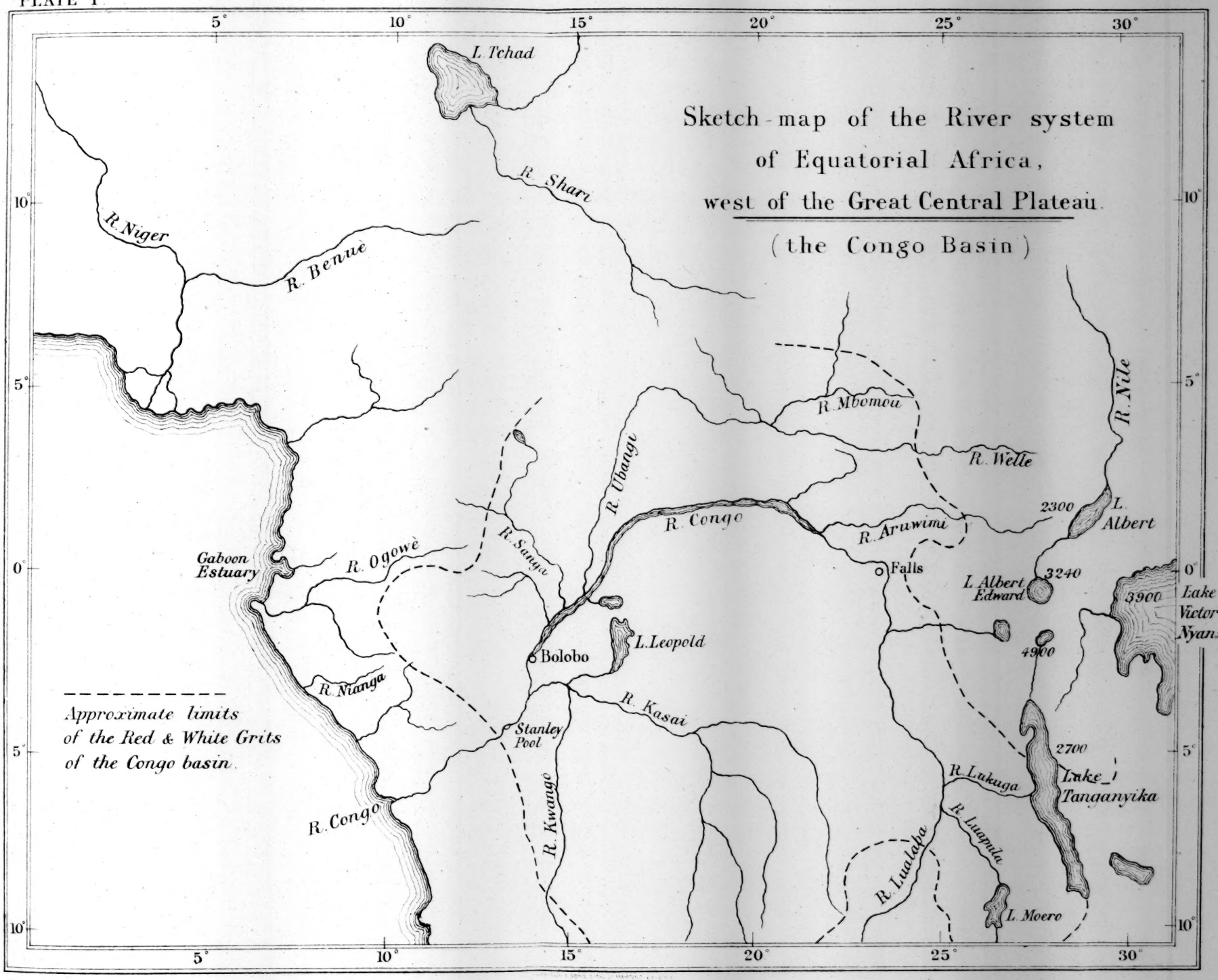
It is further pointed out in the appendix, that, besides the resemblance between Jurassic and Tanganyikan gasteropods noted by Mr. Moore, there are other cases of what I have regarded as mere mock resemblances; but in order to appreciate such cases it will be necessary to study the appendix closely, which the majority of the members probably will not be inclined to do.

On the whole, taking the evidence of the *Medusa*, and the other semi-marine forms, as well as that of the halolimnic gasteropods themselves, a fairly good *primâ facie* case for the originally marine origin of these exceptional organisms has been made out, nor do these curious gasteropods appear to be in any degree of close relationship with their ordinary fresh-water companions, although most of them undoubtedly bear traces of a long probationary experience of life in fresh-water. This may

* Appendix to Part I.

† *Proceedings Royal Society*, 1898, p. 455.

PLATE 1


Sketch-map of the River system
of Equatorial Africa,
west of the Great Central Plateau.
(the Congo Basin)
L. Tchad
R. Shari
R. Niger
R. Benuè
R. Mbomou
R. Nile
R. Welle
R. Ubangi
R. Congo
R. Aruwimi
2300
L. Albert
R. Sanga
R. Ogowè
Gaboon Estuary
Falls
L. Albert Edward
3240
3900
Lake Victoria Nyanza
4900
L. Leopold
Bolobo
R. Nianga
R. Kasai
Stanley Pool
2700
Lake Tanganyika
R. Lukuga
R. Luapula
R. Lualaba
R. Kwango
R. Congo
L. Moero
Approximate limits
of the Red & White Grits
of the Congo basin.
5°
10°
15°
20°
25°
30°

be seen in the texture of the shells, the colouring, the condition of the epidermis, etc., which may be noted in some of, but not in all, the genera.

The strongest argument of all in favour of an exceptional original is the fact that, so far as is known at present, the halolimnic gasteropods are confined entirely to Lake Tanganyika, and this circumstance will incline us to look to the Congo basin, as being the place where the mystery may some day be solved.*

Before attempting to grapple with this part of the subject which will involve the study of the geological structure of large portions of Equatorial Africa, there are two independent considerations on which I might say a word.

Distribution of Jurassic faunas in intermediate areas.—The first of these considerations relates to the distribution of *known* Jurassic faunas in areas intermediate between the Anglo-Norman basin and Lake Tanganyika, so far as such an investigation can be made, and thus endeavour to ascertain if this will throw any light upon the possible Jurassic origin of the halolimnic gasteropods themselves. From the quarries of Dorset to the depths of Tanganyika is a far cry and there should be some half-way houses, some stepping stones, as it were, to bridge over the vast distance that lies between them. Mere zoological conjecture, as I have already pointed out, is not sufficient. We must have some palæontological evidence in corroboration of the intimate relationship claimed to exist between the two gasteropod faunas, *i.e.*, between the real fossils and those molluscs which are only archaic in their internal development. In the first place, then, I may say that in this country the peculiar gasteropod fauna which characterises the Inferior Oolite of the Anglo-Norman basin can hardly be traced above the Lower Oolites, though a stray form may linger in the Callovian or even the Corallian of Yorkshire. In middle France a repetition of this peculiar fauna is seen in the Callovian of Montreuil-Bellay. When we trace the Jurassic faunas into the south-west of France, although there is much in common with parts of the Inferior Oolite of our own country, yet the analogy, as far as gasteropods are concerned, is mainly confined to such genera as *Nerinæa*.

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* The fact that a species of jelly-fish identical with the one in Tanganyika has recently been discovered in the Victoria Nyanza, but slightly affects the argument as regards the halolimnic gasteropods. We can scarcely doubt that the more mobile organisms have had opportunities of establishing themselves from the great centres of distribution in a way which is denied to the more sedentary molluscs.

Out of about thirty genera of gasteropods quoted in Dr. Glangeaud's list from the Lower Oolites of the south-west of France the genus *Purpurina* does not appear at all, whilst the genus *Amberleya* is restricted to a single unnamed species. On the other hand the genus *Purpuroidea* is recognised.* Going further south again, we look to Choffat for information as to the Jurassic faunas of the Iberian peninsula. Hitherto, I have been unable to come across any systematic list of the gasteropod fauna of the Jurassic beds, though I note in the *Faune Crétacique du Portugal*,† a species of *Purpuroidea* described by that author. There are, however, throughout Choffat's numerous publications many lists of Jurassic fossils, yet I can find nothing which might lead one to suppose that the peculiar Anglo-Norman facies of Inferior Oolite gasteropods can be traced in the peninsula.

There is one very rich gasteropod fauna of Lias-Oolite age in Sicily which inspired the famous monograph of Gemmellaro: "Sui fossili del calcare cristallino della Montagna del Casale e di Bellampo, nella provincia di Palermo." The gasteropod facies of these beds possesses some forms which appear specifically identical with those of the Anglo-Norman Inferior Oolite. However, there is no *Purpurina* and only one species of *Amberleya*.

On a higher Jurassic horizon in the same island, we recognise an *Amberleya*-like form in *Eucyclus alpinus*. On the whole, however, there is nothing in this assemblage which would help us to connect this gasteropod fauna specially with the halo-limnic gasteropods of Tanganyika.

The above enumerations may be regarded in the light of a search after the stepping stones between the Anglo-Norman basin and Lake Tanganyika; and if there has ever existed, either in Jurassic, Cretaceous, or Tertiary times, any such connection, direct or second hand, between the region in which Lake Tanganyika is situated and the sea, as is claimed by Mr. Moore, such connection has most probably been from the northwards and ultimately by way of the Congo basin. At any rate the physical configuration of Africa seems to point in this direction; and since this is the case, any discovery of Jurassic faunas, such as those of Madagascar, though very interesting in themselves, and in reality much nearer Tanganyika, is of less

* *Bulletin des services de la Carte Géologique de France* (No. 50) vol. viii. (1896–7) p. 118.

† Vol. i. (1886), p. 6, Plate I, fig. 1.

importance in considering the origin of the halolimnic fauna, being outside any possible connection with the Congo basin.

African Jurassics (*Madagascar and Abyssinia*).—Briefly referring to a valuable paper by Messrs. Baron and Newton on fossils from Madagascar,* we may note that the Jurassic fossils of that region are fairly numerous, the following horizons having been determined by means of the ammonites: viz., Oxfordian, Callovian, Bathonian, Bajocian and Lias. Amongst the Gasteropoda were two species of *Cerithium* from the Oxfordian. The remainder of the gasteropods were mostly from the equivalents of the Great Oolite (Bathonian), and included *Nerita Burigniери*, M. and L. together with species of *Nerinæa* and *Natica* described by Morris and Lycett; also *Solarium* and *Trochus*, and likewise a new species of Opisthobranch of large size referred by Mr. Newton to *Trochactæonina*. Along with this limited assemblage of gasteropods occur a very considerable number of lamellibranchs. A peep at Jurassic times almost under the equator is interesting in this connection, but there is nothing in the Madagascar fauna which particularly reminds us of the halolimnic gasteropods of Tanganyika.

The very important development of Jurassic limestones in Abyssinia described by Dr. Blanford, is extremely interesting from the fact that undoubted marine beds of Jurassic age have been raised, in a district situated about 10° N. of the equator, to plateau elevations of 8,000 feet. Nevertheless, owing to their apparent poverty in gasteropods, these beds throw no light upon the question with which we are at present concerned.†

Character of Fresh-water Faunas.—The second independent consideration of which I propose to treat relates to the character of fresh-water faunas, and more especially of the mollusca, and this, though a large subject, must be treated briefly. Without going back into the very remote past, we possess a considerable number of fresh-water forms, interlarded as it were with those of marine origin, in the Coal-measures. This subject has received much attention from Dr. Wheelton Hind, and it is interesting to note that most of these forms are lamellibranchs, hence they are, to a certain extent, outside the subject more especially under consideration. Gasteropoda in the really fresh-water beds of the Coal-measures are rare.

The earliest appearance of *Paludina* (*Vivipara*) in this

* *Quarterly Journal, Geological Society*, vol. 51, pp. 57–92.

† Blanford, *Geology and Zoology of Abyssinia*, 1870.

country occurs towards the top of the Inferior Oolite, where it is extremely local; and as a proof of the conservative character of some fresh-water organisms, always supposing them to have lived in fresh-water, this form is almost identical with the *Paludina vivipara* of the present day. I mention this genus as being very characteristic of fresh-water; and on the higher horizon of the Purbeck beds the genus is represented by two other species in great abundance, together with many other fresh-water genera. Nevertheless in the Purbecks, as in the Coal-measures, there are estuarine intercalations when a different set of fossils are found, and in the case of *Paludina langtonensis* from the Lower Oolites of Oxfordshire marine gasteropods occur in the same bed. The above statements supply a few facts as to the appearance in time of certain fresh-water organisms; but the question of their origin seems scarcely to have got beyond the range of conjecture. However, it is in the Coal-measures and in some members of the Jurassic system that the question of the origin of fresh-water molluscs can best be studied at present. The remarkable uniformity in general character of these organisms over very wide spaces is itself a problem as yet by no means solved.

Before proceeding to study the geology of Equatorial Africa as in any way affording a possible clue to the origin of the halolimnic fauna and especially the gasteropods, which present such a contrast to the average fresh-water molluscs of Tanganyika or of any other African lake, we might consider a possible explanation, which has already been put forward, viz., that some of the halolimnic genera, such as *Paramelania*, for instance, might be related to such a stock as *Pyrgulifera*,* a fossil from fresh-water beds of the Upper Chalk in southern Europe. As far as external appearances go, the halolimnic *Paramelania* resembles the Cretaceous fresh-water *Pyrgulifera* quite as much as it does the Jurassic *Purpurina*, and since *Pyrgulifera* was nearer in time and moreover a fresh-water shell, it might with more probability be regarded as an ancestral form. Too much stress should not be placed on the resemblance of a single genus, but it is a fact of some importance that a fresh-water genus of the Cretaceous period is conchologically as like the old *Purpurina* as any of the Tanganyika shells.

On the possible transference from marine to fresh-water con-

* Figured on p. 343 of the *Tanganyika Problem*, and referred to on p. 335.

ditions.—If we accept, merely for the sake of the argument, the marine origin of the Tanganyika halolimnic gasteropods, and still further if we suppose that they are derived from certain indicated Jurassic forms, it becomes a question when and where the transference from marine to fresh-water conditions was effected; in other words, when and where did their ancestors cease to be marine molluscs and become fresh-water ones. I have already said that it is to the immense Congo basin that we must look for any indications on the subject; but before making any attempt in this direction it may be as well to point out the difficulty in supposing that this transference was effected anywhere in the Tanganyika region itself. If such a transference ever took place we should seek for it rather in some region where Jurassic beds are known to occur, or at least in their neighbourhood, unless we leave everything to mere conjecture. Again the question when, *i.e.* to say, at what geological period, did the transference take place is equally important. The original Jurassic stock of our hypothesis must have existed as Cretaceous molluscs during the Cretaceous period and as Tertiary molluscs during the Tertiary period. It may be argued that these considerations are in favour of an early separation from a marine area, since fresh-water conditions are held to be conservative of form, and consequently the more remote in time the transference took place the less likelihood of change in the morphology of the shells.

Undoubtedly, in the long run, these questions of when and where, which I have put before the members of the Institute, must be determined by geological and above all by palæontological considerations. The nearest known Jurassic fauna of any importance which has hitherto been described is that of north-west Madagascar distant in an air-line from the south end of Lake Tanganyika about 1,400 miles, and almost on the same parallel of south latitude. The improbability that the halolimnic stock was derived from this source has already been indicated, owing to the physical structure of East Equatorial Africa, which we shall presently proceed to study. It is on the whole a fortunate circumstance for the hypothesis of a Jurassic origin for the Tanganyika stock that this is the case, for in these Jurassic deposits, which would have the advantage of being under the same conditions with respect to latitude and presumably in the same zoological province as the area of Tanganyika in Jurassic times, *there is not a single genus of gasteropods which has any especial resemblance to the halolimnic gasteropods of Tanganyika.* See ante, p. 347.

Jurassic fossils of the Mediterranean basin.—Hence, if we still cling to the notion of a Jurassic origin, we must go further afield and direct our attention to other Jurassic deposits and especially to those of the Mediterranean basin, as being more likely to give us some inkling of a possible derivation in this direction. I have already referred to the very rich deposits of the Lias-Oolite in Sicily, but we may come to Africa itself, where, in the extreme north, marine Jurassic and Cretaceous beds have been fairly well exploited, both in Algeria and Tunisia. Now, as a proof of the apparent poverty of the Jurassic beds in Gasteropoda, I would observe that Coquand* was only able to enumerate one species, although the Cretaceous and Tertiary beds of this region account for over fifty species of Gasteropoda. It may be noted that *Voluta*, *Strombus*, *Fusus* and *Buccinum*, are quoted from beds of Cretaceous age in Algeria, but this Gasteropod fauna in its entirety has nothing in common with the Tanganyika halolimnics beyond a doubtful shell referred to *Trochus*. In Tunisia† the most ancient formations are those of Jurassic age, forming some of the mountain cores such as Zaghouan. In that country the ammonite fauna is characteristic of certain stages of the Jurassic system, but no gasteropods are mentioned. Still following the Mediterranean coast, when we come to Egypt the Jurassics fail us entirely, and beds of Cretaceous age rest directly on the Archæan.‡

It is not necessary to pursue this line of investigation further beyond observing that if there are any stepping stones between the Anglo-Norman basin and Central Africa *quâ* Gasteropods, they remain to be discovered. I will now direct attention to another aspect of the Tanganyika problem, viz., the Geology of Equatorial Africa, more especially in connection with the physical history of the Congo basin.

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* *Géologie et Paléontologie de la region sud de la Province de Constantine*, *Marseilles*, 1862.

† *Expl. de Carte Geol. Provisoire*, par Aubert, *circa* 1890.

‡ By this name I propose, without prejudice, to indicate the Crystalline complex which is the foundation-stone of the African continent.

Part II.

Outlines of African Geology with Especial Reference to the Central Regions in which Lake Tanganyika is Situated.

It need hardly be observed that Africa is an extensive though well-defined continent, and from its size it might be expected to exhibit considerable variety of rock formation. Yet this is by no means the case, since the proportion of crystalline rocks and barren sandstones is so great that its life history has been, for the most part, but obscurely written. If the medals of creation were ever struck here in any considerable quantity they have since been in a great measure destroyed. The absence of fossil evidence is especially noteworthy in the equatorial regions, which form the special ground of our inquiry.

Roughly speaking for geological purposes the whole of Africa might be divided into three divisions of very unequal size.

(1) *The Northern Division.*—This may be considered as part of the Mediterranean basin, and indeed, almost as European for geological and orogenic purposes, always regarding the Atlas range and its dependencies as being under the same tectonic system as the Alps. Although the precise boundaries of this division can scarcely be defined, it is a limited area and by no means deficient in marine fossiliferous rocks. In Part I, under the heading of Algeria and Tunisia, some of the palæontological features of this division have already been indicated. Marine beds of Mesozoic and Tertiary age constitute the bulk of these rocks. Morocco may be included in this category.

(2) *The Region of the Great Deserts* constitutes the principal part of the second division. Prof. Cornet* tells us that this is characterized by the horizontality of the palæozoic beds, as though the area had not been one of disturbance for a long period. He also says that there is a great hiatus in the formations of this region, extending in time from the Carboniferous to the Cretaceous.

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* "Formations postprimaires du bassin du Congo," *Ann. Soc. Géol. Belge*, vol. 21 (1893–4).

Egypt might be included in this district, where, as in the case of the Nubian sandstone, beds of Cretaceous age rest on the Archæan. Altogether the Cretaceous and Tertiary beds of this region are analogous to those of Syria and of countries still further to the eastward. The southern extension of the great Cretaceous overlap in this area is not exactly known; but De Lapparent* has recently announced the discovery of Eocene fossils on the frontier of Sokoto due west of Lake Tchad. He also announces the discovery of an upper Cretaceous echinoid, believed to be from Belina, which is 300 miles north of the same lake.

The full significance of these discoveries can only be realised by the aid of a map; but among the results thus obtained we find that marine deposits of Mesozoic and Tertiary age, as proved by their fossils, are now known to exist within 14° north of the Equator. Indeed there is no reason why a considerable portion of the basin of Lake Tchad should not be underlain by Cretaceo-Eocene formations, which in all probability extend from the Atlantic coast of Senegal to the crystalline rocks of the Ethiopian Highlands. The effect of this would be that a much larger portion of Northern Africa than hitherto supposed must be included in our second division, though the limits between this and the third, or peninsular division, cannot yet be defined. There is, however, one marked difference between our second and third divisions, which cannot be too soon realised, viz., that in the second division fossiliferous marine beds of Mesozoic and Tertiary age penetrate into the heart of the continent, whereas in the third division such beds occupy but a narrow fringe between the sea and the peninsular massif. Thus, the physical history of the two regions is entirely different.

(3) *Peninsular Africa.*—Constitutes the third division, and this may be divided as follows:—

Section a. The Cape Beds, which have now been studied for a long time, and which it is necessary in some measure to refer to, if we would endeavour to understand the geology of Equatorial Africa. There is a useful summary of these beds in a recent issue of the *Geological Magazine*,† which I condense as follows:—

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* *Bull. Soc. Géol. France* (4) III, No. 3, p. 299 (1903).

† December, 1903, p. 569. See also Seward, *op. cit.* November, 1903, who deduces the age from plant evidence.

	Beds.		*Age.*
	Superficial Deposits	....	Recent, etc.
Coastal	Pondoland Series	....	Cretaceous.
Coastal	Uitenhage Series	....	Wealden.
Karoo	Stormberg Series	....	Rhætic.
Karoo	Beaufort Series	....	Triassic.
Karoo	Ecca Series	}	Permo-Carboniferous.
Karoo	Dwyka Series	}	Permo-Carboniferous.
	Cape System	....	? Old Palæozoic.
	Pre-Cape Rocks	....	Archæan.

The beds above referred to the Cretaceous and Wealden are simply strips along the coast, and it may be said generally of the principal system, viz., the Karoo, that its fauna and flora are entirely fresh-water or terrestrial. The older beds on which the great Karoo system unconformably rests contain no marine fossils. It is probable that the beds marked as Rhætic were formerly regarded as Triassic.

Section b.—We now come to consider the geological structure of *Equatorial Africa* adjoining the Cape Beds, which lie to the south. With certain exceptions presently to be described, the beds of this region coincide geographically with the Congo basin. Cornet says of this region that it is constituted by depressed massifs, formed of Archæan and Palæozoic beds much folded; these are covered by beds almost horizontal extending over immense distances, consisting of conglomerates, sandstones and clay schists, all utterly unfossiliferous. This is the unpromising region which we have to study with some degree of detail, but before doing so it will be necessary to glance at the history and structure of the peculiar mountain chain, which though it hangs to the eastern side of the continent, is called by Mr. Moore the great Central Range.

The mountain-chain or plateau-range of East Africa.—In the above geological disquisition we must not lose sight of our main object, which is to account, if we can, for the presence of the peculiar halolimnic fauna of Lake Tanganyika. Now this lake, which has a length from north to south of 400 miles, lies at the junction of the Great Central Range with the enormous Congo basin. We shall consider the structure of the Congo basin in some detail presently, but a few words as to the peculiar mountain system with which the lake is connected ought to be useful. If we want to account for anything, we must understand the position on all sides.

This mountain chain is largely volcanic in its composition, and it will be sufficient for our purpose if we take our start from the great volcanic mountain mass of Abyssinia, whose geological

features, to a certain extent, resemble those of the peculiar mountain plateau-region which is characteristic of Equatorial East Africa. Isolated volcanoes, now extinct, such as Elgon, Kenya and Kilima-Njaro rise to heights, in the two latter cases, of over 18,000 feet, but the most characteristic feature is the double chain of depressions which contain the numerous longitudinal lakes of Equatorial Africa. This system, which may be said to commence with Lake Rudolf, just south of Abyssinia, bifurcates, the eastern and smaller arm containing such lakes as Baringo (3,200 feet), and Navaisha (6,200 feet), whilst the western, or more important arm, includes the uppermost Nile-valley and such lakes as the Albert Nyanza (2,300 feet), the Albert Edward (3,240 feet), and Kivu (4,900 feet). This latter lake, as Mr. Moore has shown, formerly belonged to the Nile-valley system, but owing to volcanic extravasations the drainage has been reversed and its waters now find their way into Lake Tanganyika (2,700 feet). The two arms of this double series of longitudinal depressions are regarded as to a certain extent coalescing in the great lake of Nyassa (1,500 feet), where the system of these peculiar longitudinal depressions may be said to terminate. The mountain system of East Africa, in another form, is renewed in the Drakensberg, where the surveyors have lately found numerous indications of volcanic action. A sketch-map of the East African Lake-Chain (after Suess), modified from Gregory's *The Great Rift Valley*, is appended. (Fig. 1.)

Between the two arms of the system of longitudinal depressions ("Graben" of Suess) is situated, the wide basin of the Victoria Nyanza (3,900 feet) which has an area in miles of 270 × 225—a veritable inland sea. This constitutes a sort of broad and shallow depression in complete contrast to the Graben with their vertical walls and succession of trough faults.

Our brief sketch of the Great Central East African Range would not be complete without allusion to two very remarkable features in connection therewith, which characterize the uppermost Nile-valley system in the neighbourhood of the Lake Albert Edward. The first of these is the still active volcanic range of Mount M'fumbiro which crosses the great western arm of the Graben system at a right angle, and rises to a height of 14,000 feet in Karisimbi (extinct), whilst the rim of the crater of the still active Kirungo-cha-Gongo Mr. Moore found to be 11,350 feet. As he observes, this mass acts like a dam to the original drainage of the Graben. The chief points to note

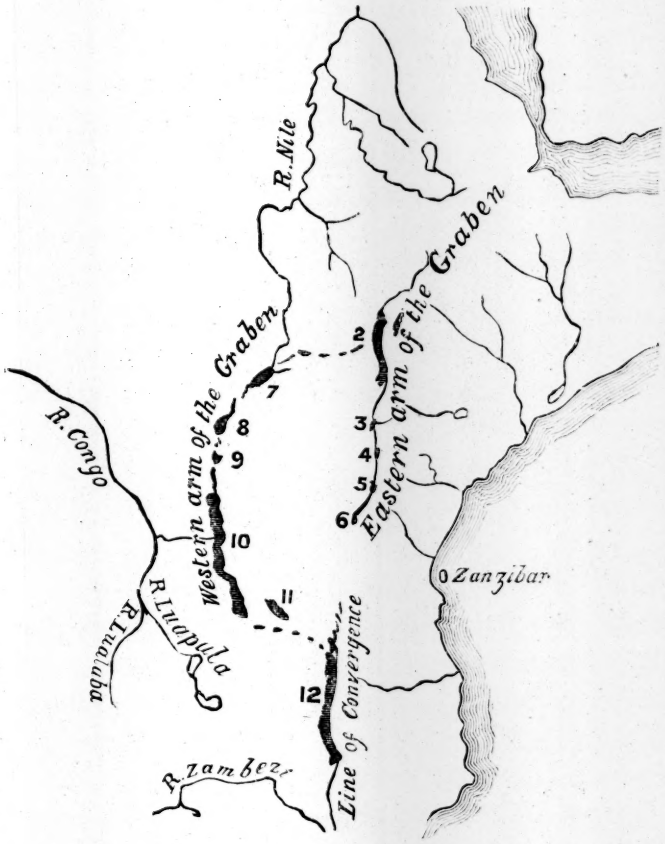


FIG. 1.—PLAN OF THE GRABEN SYSTEM AND ITS RELATION TO THE CONGO BASIN.

Eastern Arm.

1. Lake Stefanie.
2. „ Rudolf.
3. „ Baringo.
4. „ Navaisha.
5. „ Natron.
6. „ Manyora.

Western Arm.

7. Lake Albert.
8. „ Albert Edward.
9. „ Kivu.
10. „ Tanganyika.
11. „ Rukwa.

12. Lake Nyassa.

in this case are: (1) The existence of volcanic action within the containing walls of the great western Graben. (2) The fact that volcanic action is not extinct in this region, though it

is probably fast dying out. There are yet some traces of volcanic activity in the eastern arm of the Graben, where the mountain, Longonot (9,350 feet), still shows a fresh looking crater and emits steam. The facts in regard to the existence of modern volcanic action in the Graben system is of importance in connection with any attempt to estimate the age of this mountain plateau-system, in which the Graben themselves are situated.

The second feature in connection with the equatorial portion of the Great Central chain is the existence of the short, but lofty Ruwenzori Range, whose southern extremity lies actually on the equator. Whilst the axis of the volcanic chain of Mount M'fumbiro lies at right angles to the northerly trend of the great western Graben, that of the crystalline system of Ruwenzori is approximately parallel to it. "These ranges, which rival the Alps in magnitude and in the sublimity of their scenery, lie along the eastern edge of the depression, and appear, in fact, to stand out into it beyond what was originally its eastern face."* We recognise the importance of the above observation, as it tends to show that this portion of the Graben is older than the Ruwenzori Range itself. The adjacent Victoria Nyanza plateau is mainly composed of schists and gneiss, and this class of rock usually terminates abruptly at the eastern edge of the Graben where the depression ensues. But opposite Ruwenzori, instead of being broken off at the edge of the depression the gneiss and schists are bent and piled upon the steep flanks of the mountains themselves, which in their more central portions are found to consists of massive old amphibolites. These latter are, most probably, the base of the Archæan, as developed throughout the greater part of Equatorial Africa, and these amphibolites seem to have been thrust up through the overlying gneissic and schistose layer.†

Geology of British East Africa.—Having paid some attention to the physical structure of the Central Range with its associated Lake Chains, it would not be amiss just to glance at the geology of the equatorial region of East Africa and its relations to the remarkable system of Graben already partly described. In this respect we cannot do better than follow Gregory in his description of the region between the Indian Ocean and the Victoria Nyanza, which includes the eastern arm of the Graben system. The subjoined section, which lies

* Moore, *The Tanganyika Problem*, p. 94. He gives the altitude of the highest peaks at about 16,500 feet.

† *Amphibolites* are igneous rocks in which hornblende is a chief constituent; diorite is a common variety.—E. H. (Ed.)

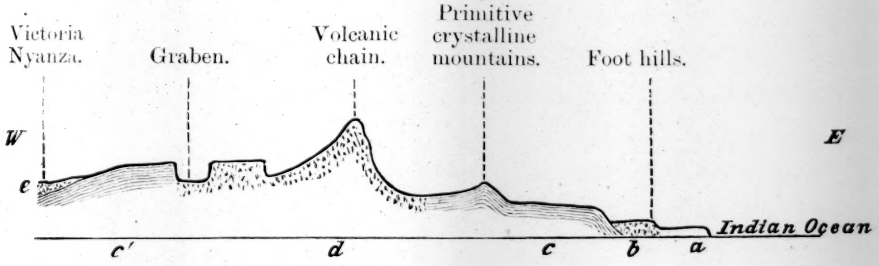
almost on the Equator, will serve not only as a description of the immediate region, but may in many respects be regarded as typical of Peninsular Africa, both east, south and west.

In particular the section shows:

(1) That fossiliferous deposits are a mere coastal fringe, or at least get no further inland than the Foot Hills, and,

(2) The enormous development of old crystalline and more recent volcanic rocks.

FIG. 2.—SECTION ACROSS BRITISH EAST AFRICA (AFTER GREGORY: "RIFT VALLEY," p. 222.)



GEOLOGICAL SIGNS.

(*a*) Coastal deposits: raised coral-reefs and old sea beaches with much wind-borne sand.

(*b*) The foot plateau. The seaward portion consists of shales, etc., of middle Jurassic age as proved by their ammonites; the middle portion of bright coloured sandstones, probably of Triassic age, but without marine fossils; the western portion of shales of probably Permo-Carboniferous age, with land plants and fresh-water mollusca (*Palæanodonta*).

(*c*) The portion of the Archæan rocks to the eastward of the volcanic region.

(*d*) Volcanic region, consisting of plateaux, mountains (Kenya, Kilima Njaro, etc.), and Graben.

(*c'*) Archæan rocks west of the volcanic region. N.B.—The Archæan system is said to cover something like two-thirds of British East Africa, and there can be little doubt that it underlies the greater part of the rest.

(*e*) Lower Palæozoic rocks without fossils on the horizon of the Karagwe series—here and there on the shores of the Victoria Nyanza.

An old crystalline axis is well shown in the above generalized section, and, as we perceive, these crystalline rocks are stated to cover two-thirds of this part of the country. Indeed it has always been an idea of mine that the immense extent of old

crystallines in Peninsular Africa helps us to understand the sandy and unfossiliferous nature of the bulk of its sedimentary rocks. What we now see are merely the eroded stumps of crystalline masses which once towered in the air, but which have been riven for ages by equatorial storms and rains, and their material distributed by torrents, rivers, and backwaters, so as to help to level up the surface. In this particular case the crystalline system has been invaded by an enormous extent of volcanic extravasations, and if we wish to discover the age of the Great East African Central Chain, as it now exists, we must endeavour to ascertain the period during which these phenomena have been in operation. The origin of Lake Tanganyika itself depends upon these considerations. That this period is post-Jurassic, there can be little doubt, for the strip of Jurassic rock near Mombasa is traversed by dykes, which seem to be connected with the general mass of extravasated matter on the central plateau. It is probable, however, that a much later date may be assigned. In this connection I would refer to Dr. Gregory,* who places the first plateau-eruptions in the Cretaceous, probably towards the close of that period, as is the case with the great basaltic outpourings of Western India. From this time up to the Pleistocene there have been, according to this author, a succession of eruptions and coast-movements, and he places the first series of Rift-Valley faults (Graben) in the Upper Eocene and the second series in the Pliocene. These statements are made, principally with reference to the eastern arm of the Graben system, but it would probably apply also to the western arm in which Lake Tanganyika is situated. It is pretty clear, however, that volcanic eruptions have taken place, as we now know, down to the present time, and that earth movements have continued, for some of the fault scarps, Dr. Gregory observes, are so bare and sharp that they must be of very recent date.

Enough has now been said with regard to the anomalous history and condition of the Great East African Central Chain and its double string of lakes of depression. Tanganyika is the largest and most peculiar of all these, and its origin is intimately connected with the above considerations. We may believe that its initiation may have taken place in early Tertiary times, but that both its drainage area and also the great Rift in which it occurs have undergone some modification owing to the instability of the earth's crust in that region.

* *The Great Rift Valley*, p. 235.

Geological structure of the Congo basin.—The above considerations present to us only one phase of Tanganyika's history. If we desire even to try to account for its peculiar fauna we must now turn to another factor in the case, viz., the geological structure of the Congo basin, with which it seems, almost by accident, as it were, to be connected. This is a very large subject, and the region under consideration is quite the converse of the one previously described; for we are about to deal with an immense circular area having only an elevation of from 1,000 to 2,000 feet above sea level, and which, for the most part, seems to have been free from tectonic disturbance. It might be thought there would be immense variety of formations in this region, but if the Belgian and French geologists, whom I shall presently quote, are correct, we have the old story over again:—a rim of crystalline and, possibly, palæozoic rocks, with absolutely unfossiliferous sedimentaries, largely consisting of sandstones, dumped down in the centre.

The best evidence we obtain of the general structure of the Congo basin is derived from the writings of Professor Cornet, of Mons, supplemented for the French Congo by those of Mons. Barrat, a mining engineer, and inspector of public works.* The first mentioned author is a geologist of great experience, and his earliest work in this region (Katanga) relates to the geology of the Uppermost Congo in the basin of the Lualaba, which is almost in touch with Tanganyika itself. Before venturing, however, to deal with this ground, I will bring to your notice Professor Cornet's experiences on the Lower Congo. The railway from Boma to Stanley Pool has materially helped the engineer to obtain a fairly accurate idea of this piece of country. It is true that this railway is only 350 kilomètres (216·35 miles) in length, and that the distance from the outlet of the Lukuga on Lake Tanganyika, measured in a straight line along the sixth parallel of south latitude, is nearly 1,300 miles, yet the section traversed by the railway and prolonged to about the neighbourhood of Bolobo, appears to be the key to

* *Cornet.* "Terrains anciens du Katanga (expédition de 1891–93)," Liège (1897).

Cornet. "Observations sur la géologie du Congo occidental." *Bull. Soc. Géol. Belg.*, vol. x (1896).

Cornet. "Études sur la géologie du Congo occidental." *Op. cit.*, vol. xi (1897).

Cornet. "Les formations post-primaires du bassin du Congo," *Ann. Soc. Géol. Belg.*, vol. 21 (1893–4).

Barrat. "La géologie du Congo Français." *Ann. des Mines*, Livraison d'avril (1895).

the structure of nearly the whole basin of the Congo. I may be pardoned, therefore, if I dwell upon this section on the Lower Congo in some detail.

The western Congo may, from a geological point of view, be divided into four zones from west to east as follows (see Fig. 3, page 361.)

I. The Maritime Zone.
II. The Crystalline Zone.
III. The Calcareo-schistose Zone.
IV. Zone of the Sandstones.

I. The Maritime Zone. — This consists of old estuarine deposits, and more particularly of fragments of Tertiary beds, Cretaceous beds, and of continental pre-Cretaceous sandstones. It is interesting to note that the only fossiliferous beds whose age may be known from their contents, constitute a narrow and insignificant fringe on the borders of the Atlantic, just as we have seen to be the case on the east coast of equatorial Africa (see Fig. 2, p. 357). All the other zones are without any definite traces of organisms.

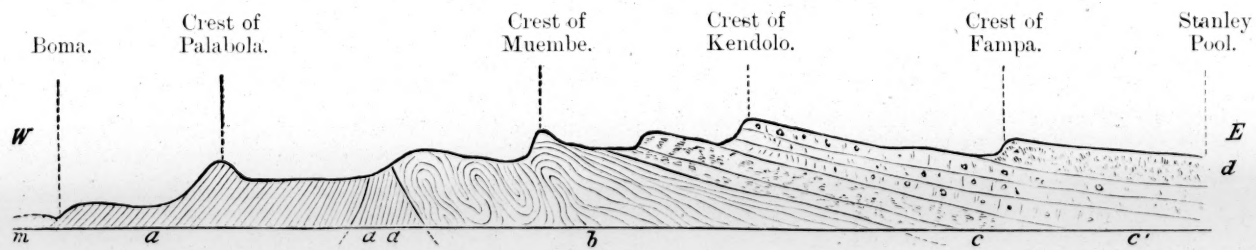
II. The Archæan and metamorphic beds.—The Archæan is well represented on the Lower Congo from the granitoid gneisses of Boma, in the west, to the chlorite and sericite schists of the higher portions. The dip is generally towards the west at variable angles, which are sometimes low. Both north and south of the Congo this zone can be traced for some distance. The so-called metamorphic beds are less crystalline, and in some cases calcareous.

III. The calcareous-schist system.—There is a massive conglomerate at the base, and this is succeeded by schistose argillaceous limestones. The middle member consists largely of marbles, whilst the highest beds are calcareous schists with silicious concretions. The beds of this system exist in a series of synclinal basins indicative of a thrust towards the west, and with a diminution of folding as one advances eastwards, until the beds pass under the felspathic grits of the fourth zone with a slight dip to the eastwards. The age of these beds is uncertain, but it is thought that part of them may represent in time the Devonian of other countries.

Zones II and III represent the rim of the basin in which the nearly horizontal sandstones of the fourth zone were deposited.

Zone IV. Zone of the Sandstones, or beds of the Congo basin proper. These are the beds to which Professor Cornet more

FIG. 3.—DIAGRAMMATIC SECTION ON THE LOWER CONGO BETWEEN THE ATLANTIC COAST (W.) AND STANLEY POOL, ABOUT 1,000 FEET ABOVE THE SEA (E.) (AFTER CORNET).



m.	Coastal deposits	Zone I.
a.	Archæan	Zone II.
aa.	Metamorphic	
b.	Calcareous schist system	Zone III.
c. & c'	Red Felspathic Grit system	Zone IV.
d.	White Friable Sandstone system ...	

N.B.—The beds of Zone IV are in complete discordance on the underlying rocks, and constitute the "formations post-primaires" of Prof. Cornet.

particularly alludes in his paper on the "Formations post-primaires." The lowest, or *Red Felspathic Grits*, is divided into two sections by a slight unconformity. It reposes in complete discordance upon the flanks of Zone III. There is a great variety of detrital matter in this formation, including conglomerates, fine grained sandstones and argillaceous schists, but one of its characteristics consists of thick beds of grit largely charged with big grains of altered felspar causing a reddish or brownish tinge. These beds correspond to the "couches de Kundalungu" of the highest Congo (Lualaba), and form part of the margin of Lake Tanganyika, as we shall see presently. On the Lower Congo the Red Felspathic Grit series extended to the westward of its present outcrop, as shown by outliers, possibly as far as the crystalline zone.

The upper portion of Zone IV, *d* of the section, which is strongly in evidence near Stanley Pool, extends up the river as far as Bolobo. It consists of white or yellowish silicious sandstones, very pure, soft and friable under the fingers, forming beds several hundred mètres in thickness and having a wavy and current-bedded stratification. Enormous sarsens attest the former presence of these beds in areas where the softer material has been removed by denudation. The beds of this system, in this region, are nearly flat, or with a slight dip to the eastward. They correspond to the "couches de Lubilache" of the Lualaba district, and may be known as the *White Friable Sandstones*.

It will not be necessary to carry the geological *résumé* of the Lower Congo any further, beyond pointing out one or two matters which may have a bearing in future discussion relative to the fauna of the Middle Congo, and, in consequence, of Lake Tanganyika. In the first place it must be borne in mind that from Stanley Pool to Boma the present river Congo has cut for itself a passage through what may be regarded as the western coastal range in a series of falls and rapids which precludes any present connection with marine conditions. We cannot doubt that during the initiatory stages of this escape from the interior, the waters of the Congo basin selected the most depressed portion of the coastal range, which thus presents an appearance, in section, of less importance than would be the case either to the north or the south of the river's course; also denudation has been active in lowering the rim of the original basin. It may be mentioned in this connection that the coastal range in the north of the French Congo (province) attains elevations of 1,500 mètres in the "Monts de Cristal,"

which are of granite. Secondly, it must be remembered, that, as far as what we may term the solid geology is concerned, the White Friable Sandstone series is the highest in the sequence of the beds which form the vast interior. These are often concealed by horizontal beds of clayey and sandy alluvium (silt), dating from a period when the mean level of the river was higher; also by spreads of what the French geologists call "Laterite." Even these alluvial beds seem devoid of organic remains, except that in one case shells of *Æthería* are mentioned.*

Having thus briefly considered in some detail the material of which the Congo basin, in a geological sense, is constituted, we are now in a position to glance at the structure and physical history of that immense area, including some attempt to fix the chronology and parallelism of the two great sandstone systems, which probably cover more ground than any other sedimentary beds throughout Africa. Cornet, in speaking of the physiography of the Congo basin, describes it as an immense "vat," whose peripheral margins are always higher than the central region.

The periphery of the Congo basin (Plate I).—The western portion we have already studied in the traverse from Boma to Stanley Pool. Although the topography varies throughout this immense circle, the geological sequence is pretty much what we have seen. Thus, on the southern margin, the watershed between the Congo and the Zambesi, towards the sources of the Lualaba, runs from elevations of 4,000 feet to 5,000 feet. On the south-east the headwaters of the Congo-Luapula proceed from a region of gneiss, mica schists and argillaceous schists with granitic massifs, which extend between lakes Nyassa and Tanganyika. The "ancient rocks" of Katanga, so well described by Cornet, of course form a part of the general periphery in these regions. It would be well to mention here that, although such ancient rocks are, in the flatter parts of the basin, covered

* There is an article by Stainier (*Trans. Inst. Mining Engineers*, vol. 15 (1898) p. 491), in which the author, besides summarizing the results of Cornet and others on the solid geology of the Congo basin, gives a very useful abstract of the *superficial formations* of this immense area. These include (1) Products of the alteration *in situ* of subsoil rocks; (2) Products of decomposition on slopes under the influence of rainfall; (3) Alluvial deposits in watercourses; and (4) Ancient alluvial deposits. It can readily be understood that the solid geology of the Congo basin is largely masked by some one or other of the above conditions, to say nothing of vast districts under water and swamps.

by one or other of the sandstone systems (formations post-primaires), yet the latter have been cut clean through by streams in many places so that the framework and bones of the skeleton are occasionally displayed throughout the vast region under description.

The eastern margin of the periphery calls for especial notice, as Professor Cornet considers Tanganyika to be within the limits of the original basin, since the Red Felspathic Grits extend to the east as well as to the west of the lake. Its eastern affluents descend from a granitic or metamorphic district stretching towards the east and also bordering the lake for a considerable distance. When we come to deal more especially with the geology of the shores of Lake Tanganyika it will be seen that these Red Felspathic Grits, almost horizontal in many places, are occasionally tilted in this region, showing that Tanganyika is within the influence of the disturbances in connection with the Great Central or East African Range, whereas the Congo basin, as a whole, is outside these influences. The south end of the lake is bordered with red and variegated grits belonging to the Red Felspathic series which are horizontal and have been transformed by metamorphism into a kind of quartzite with intercalation of eruptive rocks. At the outflow of the Lukuga are seen grits and red schists (of the Red Felspathic group) which continue for a distance of 120 kilometres westward from Tanganyika. At this point (Wabenza) they are covered by the white friable schists (White Friable Sandstone) of the centre of the basin. This formation also prevails at Nyangwe, but the Red Felspathic Grits reappear at Stanley Falls.

The limits on the north-east of the periphery are constituted by the western lip of the western arm of the Graben, which contains the lakes belonging to the Upper Nile. The region of the sources of the Aruwimi consists of crystalline rocks. On the north gneiss occurs at several points between the basin of the Uellé and the White Nile.

On the north-west there is a sandstone plateau of an altitude of 2,000 to 2,800 feet, which occupies the meeting ground of the Shari, Congo and Nile basins, and falls to the north in a plain some 400 feet lower, watered by the Auk, an eastern branch of the Shari, the principal feeder of Lake Tchad.*

* Chevalier, quoted in the *Journal of the Royal Geographical Society*, vol. 22, p. 569 (November, 1903).

This completes the periphery of the Congo basin as at present constituted.

Suggested correlation of the beds composing the interior of the basin.—Having completed the circuit of the Congo basin, we must next endeavour to ascertain something of the geological history of this vast tract and its constituent elements. The first question we ask ourselves must be, what is the approximate age of these two great interior sandstone formations? Without fossils, terrestrial, fresh-water or marine, to guide us, this can only be done by way of inference and analogy.* Cornet calls them post-primary, *i.e.*, to say, they rest in almost horizontal layers, for the most part, either on crystalline rocks or on old palæozoic rocks inclined at high angles. This is very much the case with the Karoo beds at the Cape, which are in position analogous to the two sandstone series of the Congo. The Karoo beds fortunately contain a fairly abundant fauna and flora, which is wholly terrestrial and fresh-water. The geological position of the Karoo beds is pretty well known, and I must refer to a previous statement on this subject (see page 353). We are not altogether without links in the chain of evidence.

A paper appeared lately in the *Quarterly Journal of the Geological Society* by Mr. Molyneux† on "The Sedimentary Deposits of Southern Rhodesia," where a provisional classification of the several formations, down to the Zambesi, was suggested. Beneath a series of sandstones and grits, capped by volcanic rocks, occur some 800 feet of beds containing workable and impure coal and also some recognizable fossils (Matobola beds). The interest of these consists in the fact that scales of the fish *Acrolepis* were recognized, the genus also occurring in the Lower Karoo, and likewise in the so-called "Drummond's beds" on Lake Nyassa. A very few lamellibranchs were obtained from the Sengwe coal-field and were described by Dr. Hind. These are small, oval, gibbose bivalves belonging to the genus *Palæomutela*, similar to species from the Permian of the Volga. A few plant remains were collected, and amongst others fronds of the fern-like plant *Glossopteris Browniana*, Brongn, and of some of its varieties. There can be very little doubt, therefore, that the Matobola-beds of Southern Rhodesia may be referred to the terrestrial and fresh-water Lower Gondwana system of Permo-Carboniferous age. The

* This was Prof. Cornet's view at the time he wrote.

† Vol. 59 (May, 1903) p. 266.

"Drummond's beds" towards the northern end of Lake Nyassa present similar traces of this fauna in association with a series of conglomerates, red grits and shales, and as they are not far from the south-east rim of the Congo basin their evidence is all the more valuable.*

There is good reason, on the whole, for supposing that the Red Felspathic Grits of the Congo basin are the equivalents in time, and to a certain extent in composition, of part of the Karoo system of the Cape. If this view be accepted we might roughly correlate the White Friable Sandstone series with the Upper Karoo which may possibly extend upwards as high as the Rhætic period. It should be distinctly borne in mind that no marine organisms occur in any of these beds referred to the Karoo. Mons. Barrat, in his map of the Congo basin, boldly correlates the whole of the post-primary sandstone systems of that basin with the Karoo, and in a general sense he is probably not far wrong. Cornet himself considers that the "Bassin primitif du Congo," at the period of the horizontal deposits, was separated by a chain of mountains from a region lying towards the south, south-east and east, where the beds of the real Karoo were being deposited.†

It is difficult to conceive the precise physical conditions under which these lifeless masses were accumulated during a period which may be regarded as very early mesozic (including the Permo-Carboniferous). That the mountainous periphery already described was being ground down by atmospheric causes and its products distributed by some sort of water action thoughout the central depressed area seems certain, and it is also highly probable that during the greater part of the time there was no drainage outlet, so that this part of Equatorial Africa became the dumping ground of a mass of mechanical sediments, which had no means of escape by the usual method of rivers flowing towards the ocean. But a time came, perhaps towards the middle of the mesozoic epoch, when deposit ceased to be the order of the day and these interminable sandstones themselves became subject to the laws of

* The Drummond's beds of Nyassa are described as a small system of grits, schists and limestones with fish (*Acrolepis*), molluscs (*Mutela oblonga*) and plant remains. Other localities are quoted where the Red Felspathic Grits contain remains of vegetation, according to the traveller, Thompson.

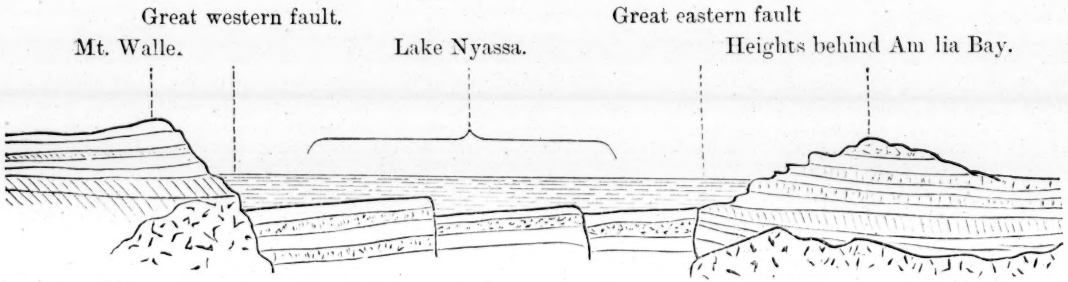
† It is admitted that the Karoo beds of the Cape constitute a somewhat indefinite system, yet within certain limits their horizon may be accepted as fairly well understood.

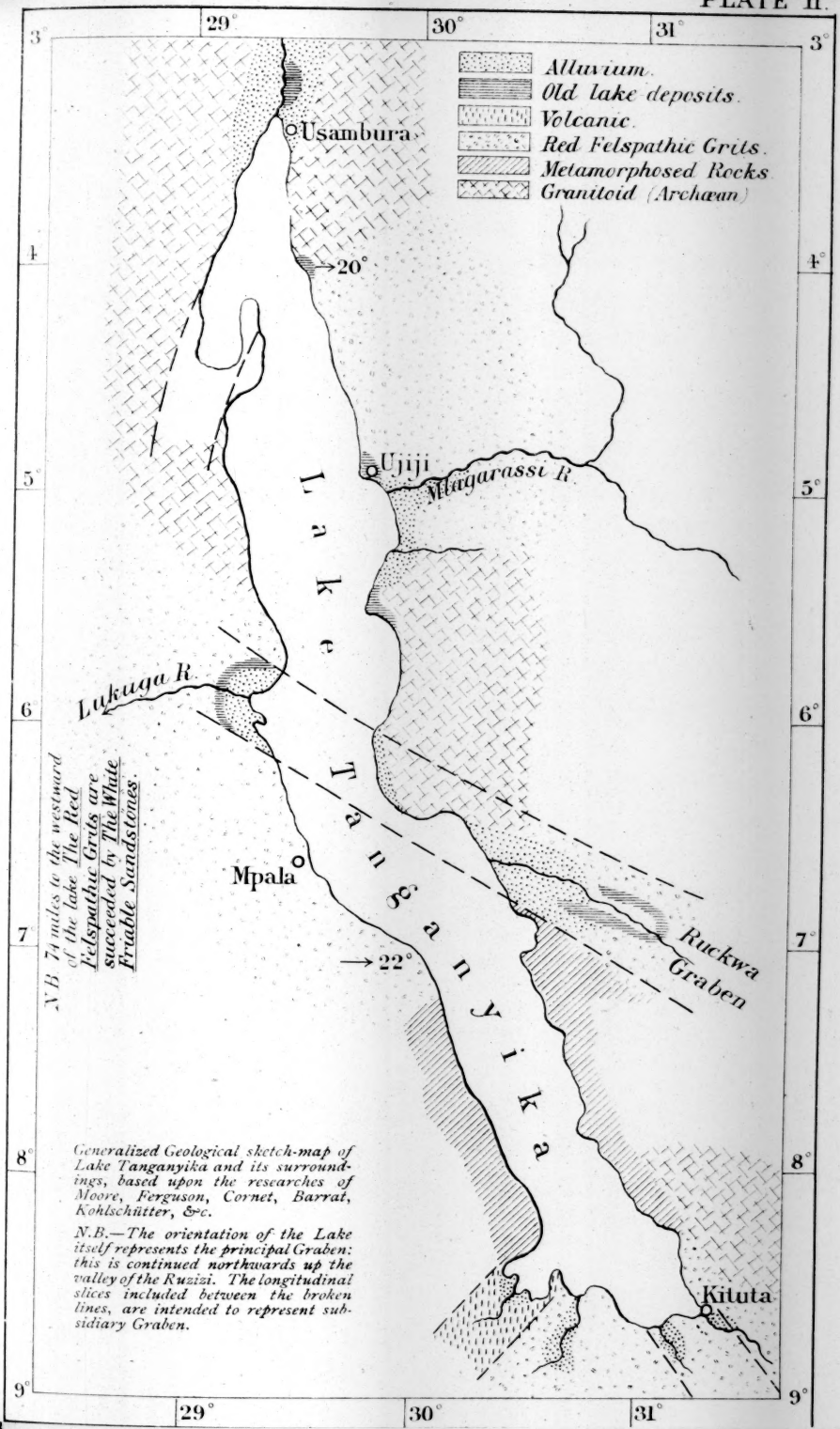
denudation. A new era had arrived, and some faint shadow of modern conditions was inaugurated. Unfortunately, there is no evidence, as far as I can make out at present, of what took place between the close of the White Friable Sandstone period and that of sub-recent and recent deposits. This interval doubtless was, during part of the time, a period of great inland waters, where the basins of the Congo, Shari and White Nile inosculated and where the fauna now exisiting in Equatorial Africa was to a considerable extent evolved, and the rivers themselves partly marked out. But enough perhaps has been said on this subject, and I must now conclude this geological disquisition with a brief description of the more immediate surroundings of Lake Tanganyika itself, inasmuch as a proper understanding of the peculiar physical features of this lake may help us to consider, if not to explain, the origin of its still more remarkable molluscan fauna.

Structure of a Graben.—Before proceeding to consider the geological features of Lake Tanganyika, I would draw the attention of members to the structure of a Graben as depicted by Mr. Moore, in the case of Lake Nyassa. This traverse which is taken through Mount Waller towards the north end of the lake, shows the relation of the Red Felspathic Grits to the underlying granitoid rocks (Archæan); and it also exhibits the system of trough-faulting which may be taken as one form of the structural arrangement of a Graben.

Geology of Lake Tanganyika.—As regards Tanganyika itself the lake occupies the principal depression in the western arm of the Graben-system of Equatorial Africa, running due north and south for 400 miles, and the present elevation of the surface of the water is stated to be 2,700 feet. There are several affluents, the principal one being the Ruzizi at the head of the lake, whilst there is only one effluent, viz., the Lukuga, which escapes through a chasm in the western walls (*? vide* Gregory, *The Great Rift Valley*, p. 3), and ultimately joins the Congo drainage system, to which at present it belongs. The discharge of the Lukuga seems to be a precarious one, and it is clear that there have been times when the water does not escape, in which case one would expect an increase in its salinity. Great depths are reached in this lake, and Mr. Moore considers that it is not all of one age, the central portion between Karema and Ujiji being regarded as the oldest. This circumstance is also true of Lake Nyassa, where in some places the bottom is so bare of recent deposit as to suggest that such portions may have been added to that lake

FIG. 4.—STRUCTURE OF A GRABEN.





Generalized Geological sketch-map of Lake Tanganyika and its surroundings, based upon the researches of Moore, Ferguson, Cornet, Barrat, Kohlschütter, &c.

N.B.—The orientation of the Lake itself represents the principal Graben: this is continued northwards up the valley of the Ruzizi. The longitudinal slices included between the broken lines, are intended to represent subsidiary Graben.

at a comparatively recent period. Oscillation of the floor and containing walls of both these great Graben lakes is noticeable in places.

In attempting to construct a geological map of Tanganyika I must be guided by Mr. Moore to a certain extent, not forgetting, however, to consult the works of Cornet, Bornhardt, Kohlschütter and other distinguished scientists. If there is obscurity, in the geology of Equatorial Africa, still there is a certain degree of simplicity as far as the composition of the several formations with which we have to deal. Around Tanganyika, though not to the same extent as around Nyassa, the basement granitoid rocks (Archæan) are strongly in evidence. Upon these at the south and south-east end of the lake in complete unconformability reposes the great sandstone and shale formation, which, we have seen, Cornet in his numerous writings on the Congo basin calls the *Red Felspathic Grits*, or "couches de Kundelungu" of the Lualaba district, and which constitute the lower division of his "formations post-primaires." Beds of this character also extend to the east as well as the west of the lake, and this part of the area now occupied by Tanganyika must have been within the limits of the original basin of deposition (see *ante*, p. 364). These Red Felspathic Grits, so horizontal for the most part throughout the basin of the Congo, are tilted in portions of the western wall and notably at Mount M'rubi, where they are said to have an inclination to the eastward. As previously observed, this shows that Lake Tanganyika is within the influence of the movements connected with the East African Plateau Range, whereas the bulk of the Congo basin is without the sphere of those influences. At the south end of the lake the Red Felspathic Grits are shown for the most part as horizontal, although, according to Mr. Moore's mapping, much cut up by subsidiary Graben which carry on the principal Graben of Tanganyika in a southerly direction. In one of these subsidiary Graben, towards the south-west, is situated both the true and the salt lake Mwero of the higher Congo, and that perhaps is about as far west as the Graben-system can be traced. In the neighbourhood of Cameron Bay there are considerable indications of volcanic eruptive matter, and, according to Cornet, much of the Red Felspathic Grits have been transformed into quartzites with intercalation of this eruptive material. These most probably are the "metamorphic" beds of Mr. Moore, which seem to occupy both sides of the southern third of the lake.

Towards the northern termination of the series which has

been subject to this kind of metamorphism, the great Rukwa Graben strikes the Tanganyika fissure at an acute angle, and it is extremely probable that this longitudinal depression, as pointed out by Mr. Moore, extends across the lake and reappears as the great gap in the western wall through which the drainage of Tanganyika has been effected. Possibly subsequent erosion may have had something to do with the deepening of the primary fissure, which thus becomes a "rift-valley" in the true sense of the term. After passing over modern lake deposits, the Red Felspathic Grits are encountered on the Lukuga as previously stated (p. 364), and extend for a distance of 120 kilometres from Tanganyika, and beyond this point are covered by the *White Friable Sandstones* which constitute the upper member of Cornet's "formations postprimaires."

It seems doubtful whether any fossils occur in connection with the Red Felspathic Grits of Lake Tanganyika. There can be no doubt whatever that the Red Felspathic Grit series of Cornet is the same as the sandstone series of Mt. Waller and Amelia Bay on Lake Nyassa, which is identified by Bornhardt with the Karoo formation, and with which are associated the so-called "Drummond's beds" with their *Glossopteris* flora and fresh-water fauna (see pp. 365 and 366). At more than one spot in the vicinity of the northern end of Lake Nyassa indisputable evidence of coal, fossil plants, shells and fish scales of fresh-water origin have been found. It seems unfortunate that the corresponding beds (*i.e.*, the Red Felspathic Grits) of Tanganyika and the Congo basin seem to be barren in this respect. At least such appears to have been Cornet's opinion, and he accounts, as we have seen, for the barrenness of these beds on the supposition that they were laid down in a basin on the west side of the primary mountain range of what is now East Central Africa.*

* Reymond (*Bull. Soc. Géol. France*, 1885) speaks of certain "schistes fossiliferes," collected by Giraud in 1881, at some distance from Mpala on Lake Tanganyika, which were said to contain a *Cyrena* and fish remains (*Lepidosteus*). This alleged discovery on Tanganyika may be the same as that mentioned by Drummond (*Tropical Africa*), where he observed that three days north of Nyassa Giraud found in the schists certain fossils which Bertrand referred to *Lepidosteus* and *Cyrena*. Moreover, Moore considers that "Drummond's beds" occur at two or three localities on or near Tanganyika, but as he mixes these up with modern lake deposits, it is not very easy to get at his meaning, the more so, since no organic remains are mentioned, other than those of the lake itself. On the whole, I conclude with Cornet, that no good evidence of fossils belonging to the Red Felspathic Grit series has hitherto been found in the Congo basin, of which L. Tanganyika at present forms a part.

The next formation in order of time is the volcanic series to which allusion has already been made towards the south-west corner of the lake, and with this may be associated the metamorphosed sandstones, etc., which appear, in fact, to be portions of the Red Felspathic Grits and not "primary metamorphics," such as those described by Cornet in Katanga. These volcanics most probably belong to the graben-system, and must be approximately of the same date as similar volcanics towards the north end of the great Nyassa-graben and elsewhere.

The latest formations in point of time are deposits derived from the lake itself, and these are of especial interest as containing the remains of the existing halolimnic molluscs. It is probable that they may be met with at many places along the shore. Mr. Moore refers especially to the line of coast between Ujiji and Usambora, where layers of modern lake-deposit, somewhat shattered, are found dipping 20° to the east conformably to the sheets of Old Sandstone on which they repose. According to the same author the flat floor of the Ruzizi valley (at the head of the lake) is composed chiefly of modern sandstones and alluvium. Higher up the valley, to about 200 feet above the present surface of the lake, his party kept passing over older and older ground, and the plains thus traversed were found to be intersected by water-courses in some cases to a depth of 90 feet, so that the older stratified materials were exposed. These strata were found to consist of brown and yellow sandstones, having a slight dip to the south, and contained many shell fragments and also some fossilised shells which could be identified as *Neothauma*, *Nassopsis* and *Paramelania*. The age of the deposit is probably Pleistocene, and not only has the water level of the lake fallen, but he thinks that the valley-flat north of Tanganyika has undergone elevation also since those days. It should not be forgotten that Mr. Moore (*Tanganyika Problem*, p. 90) states that the water of the lake is somewhat salt. He observes that it seems to be fresher now than when Livingstone and Stanley examined it. Moreover, as both these explorers aver, there are traditions among the Arabs that, within the recollection of living men, it was a lake which never flowed out at all.

Part III.—Conclusions.

1. The zoological aspect.
2. The palæontological evidence.
3. The argument from geology.

To a certain extent the probable conclusions have already been indicated in Parts I and II. of this communication, but a brief summary at the final stage may be of use. On the whole we have three main factors to guide us in the investigation, and these we will take in the order above indicated.

The zoological aspect of the question.—This is mainly studied by means of conchological comparison, and it will be seen on referring to Part I, and more particularly to the Appendix, that, in my opinion, the resemblance between the Tanganyika shells and those of our British Inferior Oolite is not sufficiently close to warrant any theory as to the derivation of the former from the latter. But, on the other hand, there is the malacological evidence derived from the study of the anatomy of the existing mollusc, which reveals a peculiar archaic character, and also a singular blending of attributes usually held to be distinct. Such peculiarities, whilst pointing to the exceptional character of this assemblage of gasteropods, fail altogether to establish any connection with the Inferior Oolite of the Anglo-Norman basin. Yet the very existence of a group of halolimnic gasteropods limited to Tanganyika, is in itself a proof that there is something remarkable about these molluscs and such a view is further confirmed by anatomical investigation. Hence these gasteropods may, in some way, have had a remote marine origin, although that need not have been Jurassic.

It has always seemed to me that the most hopeful line of research is to be sought in the waters of the Congo basin, and particularly in Lakes Bangweolo and Mwero. If the halolimnic gasteropods had their origin in the vast inland seas of this immense system, as they existed formerly, there should be some trace of them in the lakes of the Upper Congo. This, Mr. Moore informs us, is unfortunately not the case, although in Lake Mwero a genus closely approaching the *Neothauma* of Lake Tanganyika has been found. I am rather inclined to consider that the zoological evidence points to a local and restricted origin for these Tanganyika shells, and if we accept the theory of their special marine derivation, whether Jurassic or more recent, it must always be with a certain degree of doubt.

The palæontological evidence.—Since the hypothesis of a

Jurassic origin for the Tanganyika shells has been mooted, the Palæontological evidence brought forward in Part I may now be briefly recapitulated. I must confess that the possibility of tracing a connection between the Inferior Oölite fauna of the Anglo-Norman basin and the fauna of Lake Tanganyika had a considerable fascination for me, and I rather hoped that as we approached the Mediterranean basin there might have been some evidence in favour of these views. On the contrary, except in Sicily, no really important gasteropod fauna has been discovered in the intermediate areas, and even in the case of the Sicilian fossils the prevailing assemblage of gasteropods lends but little countenance to any theory of a Jurassic origin for our halolimnic shells.

These considerations were originally based upon a hope that there might be some evidence of a Jurassic derivation by way of the Congo basin, but the more I studied this part of the question the less faith I had in my original expectations. Supposing, as is by no means improbable, that there may have been a communication with Tertiary and even with Mesozoic seas on the northern side of the Congo basin at some period of its history, the misfortune is that we obtain no palæontological evidence in the direction required. If we take North Africa, the Iberian Peninsula, or even the south-west of France, wherever Jurassic deposits are known, they have never yielded a fauna approaching that of the Anglo-Norman basin, and therefore do not help us in the least towards covering the immense distance in space which exists between that classical region and the centre of Equatorial Africa. As regards Jurassic deposits within the limits of the African tropics, such as those of Abyssinia and Madagascar, we have already seen that their fauna, so far as known, has no analogy with the Tanganyika gasteropods. This, however, is a fact of minor importance, since the Madagascar deposits especially occupy a region which there is good reason for believing on geological grounds, has never had any connection with the Congo basin, in which Lake Tanganyika is situated.

The argument from geology.—Since neither the zoological nor the palæontological evidence favours the notion of an Inferior Oolite origin for the halolimnic gasteropods, we must endeavour to ascertain how far the geological history of this part of Equatorial Africa tends to throw any light upon the subject.

In Part II, I have endeavoured to sketch a brief outline of this history, dwelling more especially on the geological structure of the Congo basin, and of that portion of the East

African Plateau-chain which flanks it on the east. The importance of Lake Tanganyika in a physiographic sense is based largely upon the fact that it lies at the junction of these two very different regions, the latter a disturbed, and the former a quiescent one. As constituting a part of the western arm of the Graben-system I am inclined to the belief that it is by no means an ancient feature of the earth's crust. Much depends upon the date assigned to the East African volcanic plateau, which was probably initiated towards the close of the Cretaceous period. The Graben-system is of necessity more recent, and if this system has any connection, as regards time, with the Jordan-valley fissure it must be post-Eocene in date. I think that we may provisionally accept this date for the initiation of the Graben-system, though I should be disposed on other grounds to make it more recent still, bearing in mind that its activities are not yet extinct.

Lake Tanganyika, as Mr. Moore points out, was formed at different times, but since its existence could not precede that of the Graben-system, the oldest date that we can assign to any portion of it is Middle Tertiary. It is not contended, however, that there were no large lacustrine sheets of a different character at the time of its formation in the neighbourhood, and notably in the area now occupied by the eastern portion of the Congo basin. The geological history of this vast territory is unfortunately a blank since the deposition of the "White Friable Sandstones." All we can say is that nothing which could indicate the presence of a Jurassic Sea or even of a Cretaceous Sea has been discovered therein. There can be little doubt that the "Red Felspathic Grits" of Cornet, which underlie the "White Friable Sandstones," may be comprehended under the very wide term of Karoo, which gives us an approximate date. The overlying "White Friable Sandstones" will, therefore, be Mesozoic in age, and probably like the Karoo beds non-marine in origin.

We now come to the consideration of a very interesting question, viz., the connection between Lake Tanganyika, which is a fissure lake, with the wide and quiescent area of the Congo basin. For several years, as you are aware, geographers were in doubt as to whether Lake Tanganyika had an outlet, and when the outflow of the Lukuga was at last established it was thought that the outflow was intermittent. The conditions vary even now, I believe, according to the supply of water in the lake. But what I especially wish to point out is the peculiarity of the Lukuga outlet in a fissure lake surrounded

for the most part by lofty enclosing walls. Was this outflow caused by a cross-fissure (Graben) such as might be produced by the prolongation of the great Rukwa-Graben in the way indicated by Mr. Moore? At any rate these drainage facilities may not always have existed, and in that case Tanganyika during part of its history would be a closed water, and consequently more or less saline. Whether such conditions as these had anything to do either with the origin or conservation of the halolimnic gasteropods I do not venture to say. My endeavour has been to find any geological evidence in favour of the view that they were derived either primarily or secondarily from a Jurassic stock of Inferior Oolite age. It must be confessed that thus far my efforts have been without success. At the same time mere negative evidence must not be accepted as final.

In conclusion, then, since neither the zoological, the palæontological nor the geological evidence affords much support to Mr. Moore's theory, we must regard the Tanganyika problem in its main features as unsolved. In the present state of our knowledge we are not bound to submit an alternative hypothesis. Yet, if we still cling to the notion of a specially marine origin for the halolimnic gasteropods, the most promising quarter for a solution of the riddle is to be sought along the northern margin of the Congo basin, where it adjoins that of the Shari. This opens up the notion of a possible communication through the depression in which Lake Tchad is situated with the undoubted marine deposits of the second geological division of Africa. That the so-called "post-primary" deposits of Equatorial Africa, like their equivalents at the Cape, are, with the exception of coastal strips, mainly of terrestrial and fresh-water origin, I entertain no doubt. The only exception to this rule appears to be a Jurassic formation in Abyssinia known as the Antalo limestone.

It should be distinctly understood that I have not taken up this investigation in a controversial spirit; nor indeed, in the first instance, with a view to controverting the theory of a Jurassic origin for the Tanganyika gasteropods. If, during the course of the inquiry, I have been unable to find evidence in favour of that hypothesis, it has at least been a source of gratification to follow Mr. Moore's lead in his character of explorer and naturalist. In this way both myself and those members of the Victoria Institute who have taken the trouble to follow me must feel indebted to him for having awakened a more than passing interest in one of the many problems of Equatorial Africa.

APPENDIX TO PART I.

NOTES ON THE COMPARISONS BETWEEN THE HALOLIMNIC GASTEROPODS AND CERTAIN FOSSILS FROM THE INFERIOR OOLITE—TOGETHER WITH AN ABSTRACT OF MR. MOORE'S STATEMENTS REGARDING THE MOLLUSCA OF TANGANYIKA GENERALLY.

* Forty-six species of mollusca are enumerated (*The Tanganyika Problem*, p. 138), consisting entirely of Gasteropods and Lamellibranchs, the former preponderating. Of the latter are a number of distinct specific forms supposed to be related to *Unio*. Many of the Gasteropods belong to normal genera, such as *Limnæa* (four species), *Isidora* (two), *Physopsis* (one), *Planorbis* (three), *Ampullaria* (two), *Vivipara* (one), *Cleopatra* (one), *Melania* (three). There is also the very fine *Vivipara*-like genus, *Neothauma*, Smith, which cannot in any sense be regarded as halolimnic. Mr. Moore further observes that the normal fresh-water molluscs found in Tanganyika are specifically distinct from the representatives of the same genera occurring in the neighbouring lakes. Excluding *Neothauma* there are fourteen Gasteropodean types (p. 218) judged by their conchological characters, generically distinct, as follows, viz. :—

Typhobia.	*Spekia*.
Bathanalia.	*Nassopsis*.
Limnotrocus.	*Syrnolopsis*.
Chytra.	*Stanleya*.
Paramelania.	*Reymondia*.
Bythoceras.	*Horea*.
Tanganyicia.	*Ponsonbya*.

Out of these the following are regarded as specially representing the halolimnic molluscs, and are classified in six groups, viz. :—

Typhobia and *Bathanalia*, *Tanganyicia*, *Limnotrochus* and *Chytra*, *Spekia*, *Paramelania* and *Bythoceras*, *Nassopsis*.

It is more especially the above forms which are regarded as homæomorphic with certain fossils, chiefly of the Inferior Oolite, and this resemblance has impressed Mr. Moore so strongly, that he is disposed to consider these groups as the partially modified descendants of the old Jurassic molluscs.

As most of these comparisons were made with fossils in my own collection, I have endeavoured, in those cases where it has been possible to procure the particular Tanganyika shells, to check the resulting determinations, of course on conchological lines solely.

1. *Melania admirabilis, Smith, with Cerithium subscalariforme, D'Orbigny.*

N.B.—These shells are not referred to in the above list. On pp. 219 and 353 of the *Tanganyika Problem* are back and front views of the

* It is probable that this is not an absolutely full list.

Melania admirabilis of Lake Tanganyika—at least, I suppose that both of these cuts are intended for the Tanganyika shell, and not for the Jurassic fossil. The likeness is by implication only, for on referring to page 273 for the affinities of *Melania admirabilis* I find no recognizable account of that species. It is true that on page 269, the author makes a general attack upon the genus *Melania*; but this is rather with a view of criticising the suggested relationship of *Typhobia* to *Melanopsis*.

The shape and ornamentation of *Melania admirabilis* (judging from the figures) and *Cerithium subscalariforme* are singularly identical. There is some difference in the apertures, for in *C. subscalariforme* there is a well-formed anterior spout slightly reflexed. Not having any specimen of *M. admirabilis* in my possession, I cannot pursue the comparison any further.

2. *Typhobia horei, Smith, with the genus Purpuroidea, Morris and Lycett.*

Mr. Moore in this case does not institute any close comparison, but rather suggests (p. 350) that *Typhobia* is matched by the Oolitic fossil genus, *Purpuroidea*, "from which it is difficult, if not impossible, on conchological grounds, to distinguish it." I select *Purpuroidea Morrisii*, Buvignier, a characteristic Great Oolite fossil, to exemplify the genus.

Here the ornamentation and general strombiform character of the shell in each case is strikingly apparent. On comparing the apertures we find that, instead of the short notch of *Purpuroidea*, the inner lip of *Typhobia* is produced anteally into a narrow and reflexed spout. In other respects both the outer and inner lip in *Typhobia* and *Purpuroidea* greatly resemble each other and equally differ from *Strombus*. Whilst recognising a considerable degree of homœomorphy between the two shells from Tanganyika and Minchinhampton respectively, a comparison of the shell substance seems to suggest important differences. So far as we are able to judge from the usual calcite replacement of the fossil shell, one would say that *Purpuroidea* had a thick and heavy shell. On the other hand *Typhobia* has a very thin and fragile shell, and, despite its identification as a halolimnic shell, has all the appearances of a fresh-water genus—so much so, indeed, that its affinities with *Melania* have been suspected by some, though this would seem to be negatived by internal characters. As regards the history and distribution of *Purpuroidea*, the genus makes a doubtful appearance in the Inferior Oolite of the east of England; it is fairly abundant in limited districts of the Great Oolite and is last seen, so far as England is concerned, in the Corallian of Yorkshire. It would seem also to be fairly abundant in the Corallian beds described by Buvignier. It does not occur on a higher horizon in this part of Europe.

3. *Bathanalia howesi, Smith, with Amberleya orbignyana, Hudl.*

Bathanalia is figured on pp. 227 and 348. Of this peculiar genus Moore says (p. 228) that it is an inhabitant of deep water throughout

the southern third of the lake, and he considers that, in conchological characters, it is identical with several marine Jurassic fossils, described under *Amberleya*. He further remarks that except for its widely different shell, *Bathanalia* is structurally identical with *Typhobia*. Referring to the diagnosis of *Amberleya*, quoted in p. 346, Moore says that this would absolutely answer for *Bathanalia*. According to his view the thin shell, the absence of all trace of epidermis, and the character of the whorls, as well as the sculpture and character of the mouth, are all essentially the same in *Bathanalia* as they are in *Amberleya*.

Judging from figures only, this is the most striking of all the resemblances. I gather, however, that there are some differences in the aperture.

On p. 348, Moore has figured the back only of my specimen of *Amberleya orbignyana*. The right hand upper figure on this page is intended for an *Amberleya*, which I do not quite recognise. The two lower figures represent *Bathanalia*, back and front. It is unfortunate that no good front aspect of *Amberleya* is presented to the reader, for if the aperture in *Bathanalia* is correctly drawn, it does not possess the straight pillar lip, coming forwards almost to a point, which is so characteristic of *Amberleya*. In all other respects the resemblance is most striking, even to the angular outline of the outer lip, which in *Bathanalia* is prolonged into a short process. It should be observed, however, that there is somewhat of an umbilical opening in *Bathanalia*, whereas the shell of *Amberleya* is entirely closed.

Amberleya (including *Eucyclus*, which latter, if not a synonym, has a close relationship) is eminently characteristic of the Lias. It comes up from the Lower Lias, and culminates in the Inferior Oolite, especially in beds having a Cephalopod facies, as in the Anglo-Norman basin. Occurs also in the Great Oolite, and seems to have left this country with bed of Corallian age.*

4. *Limnotrochus thompsoni*, *Smith*, *with Littorina sulcata*, *Hebert and Deslongchamps*.

See pp. 233 and 349. It is also compared with *L. dorsetensis*, Hudl. In the possession of a black epidermis and in its general aspect *Limnotrochus thompsoni* has a certain fresh-water character. The aperture, however, is more like that of *Littorina* than of *Trochus*. The trochiform outline of the shell and the ornamentation, especially the

* Since writing the above, I have had an opportunity of inspecting a specimen of *Bathanalia* through the courtesy of Mr. Da Costa. I am more than ever impressed with the extraordinary resemblance of the spire to that of *Amberleya pagoda*, but the character of the mouth is so very different, that I conclude the resemblance of the spire to be fortuitous.

strongly bicarinate body whorl, have a singular resemblance to *L. sulcata*, H. and D. The aperture, however, presents considerable differences, and in this respect *Limnotrochus thompsoni* more nearly approaches some of the many varieties of "*Littorina*" *dorsetensis*, the chief difference being that in the latter, the umbilicus is closed and the aperture is not free as in the former case. Nevertheless, the general resemblance is sufficiently striking.

5. *Chytra* (*Limnotrochus*) *kirkii*, *Smith*, *with Onustus ornatissimus D'Orbigny.*

See pp. 229 and 350. Originally the empty shell had been described and figured by Mr. Smith (*Proc. Zool. Soc.* 1881), who classed it under *Limnotrochus*. Mr. Moore has founded for this species the genus, *Chytra*, and further observes that the shell of *Chytra kirkii* is remarkably solid, resembling both that of *Solarium* and *Zenophora* (*Onustus*).

The resemblance of *Chytra* to the Jurassic species referred to *Onustus* is very slight indeed, beyond the general pyramidal shape of the shell. One of the leading characteristics of the Jurassic *Onustus* is the imbricate overlapping of one whorl over the next one, and this feature is equally seen in the *Onustus pyramidatus*, Phillips, as in *Onustus ornatissimus* D'Orbigny. There is no trace of this kind of overlapping in *Chytra*, which, to my notion, has more the character of *Solarium*. The basal characters in *Chytra* are also different to those in the Jurassic species of *Onustus*.

Hence I fail to trace any marked resemblance between *Chytra* and *Onustus*. Nevertheless *Chytra* is perhaps the most thoroughly marine in aspect of all the halolimnic series, the shell being thick and more or less free from epidermis. Indeed, most conchologists, if they did not know its habitat, would hardly suspect that it was anything more than a somewhat aberrant *Solarium*.

6. *Paramelania damoni*, *Smith*, *with Purpurina bellona*, *D'Orbigny.*

See pp. 245 and 345, for figures. There are three species of *Paramelania* mentioned by Moore (index, p. 366) viz., *P. crassigranulata*, Smith, *P. crassilabris*, von Martens, and *P. damoni*. Other species also have been described by Bourguignat, some of which possibly belong to *Nassopsis*. The species of *Paramelania* selected by Moore for comparison with the Jurassic *Purpurina* is *Paramelania damoni*, of which unfortunately I do not possess a specimen, and must therefore rely solely on Moore's figures, pp. 245 and 345. The comparative figures are to be found on p. 345. The particular *Purpurina* there drawn is *P. aspera*, *Hudl.* from the *Concavus*-beds of Bradford-Abbas. This is a very rugose form of *Purpurina*, and its resemblance to *Paramelania damoni* (judging from the figure) is very striking; only that in *P. aspera* and indeed in *Purpurina* generally, the anterior notch or channel is more in evidence, and also more reflexed than in the majority of specimens of

Paramelania. In this respect the regulation *Purpurina bellona* (which occurs on a higher horizon than *P. aspera*) more resembles the average Paramelanias of Tanganyika. It should be remarked also that most species of *Paramelania* have a considerable amount of brown scaly or epidermal matter, and are generally thick and nassoid or purpuroid in the texture of the shell. Reference is made to the conchological similarity of *Pyrgulifera*, a genus of fresh-water shells (p. 343) of the Upper Chalk, to *Paramelania*, and this casual identification opens up several interesting questions.

7. *Nassopsis nassa, Smith*,* *with Purpurina inflata (? auctor)*.

See pp. 250 and 347. During life this mollusc, we are told, inhabits the surface rocks of Tanganyika and its shells are always richly encrusted with the green algæ which clothe the rocks for a considerable depth. It is sluggish and appears to browse within a very limited area, like the Patellas of the Ocean beach.

As regards the Jurassic fossil figured for comparison (upper figures, p. 347) under the name of *Purpurina inflata*, I should point out that this specimen is not *Purpurina inflata*, Tawney, but a peculiar unnamed form which was figured in Plate I of the "Jurassic Gasteropoda." The true *P. inflata* has a very different figure and ornamentation, but possesses a rounded and almost unchannelled aperture, having in fact the least indented mouth of all the *Purpurinæ*.

The real value of these comparisons is an unknown quantity, but the conchological resemblance of both *Paramelania* and *Nassopsis* to certain named and unnamed forms of *Purpurina* is clearly pointed out by Mr. Moore, and admitted, as I understand, by Mr. Edgar Smith. Such resemblances are interesting, but if *Paramelania* and *Nassopsis* are really different genera, as their internal structure would imply, one learns two things from this fact: (1) that the outward form of the shell is not always indicative of the character of the animal within, and (2) that two different genera of existing molluscs are compared with the one Jurassic genus, *Purpurina*.

It may be mentioned here that the genus *Purpurina* was somewhat loosely constituted by D'Orbigny, and was more carefully reconstituted by Piette and Deslongchamps, who regarded it as having relations on the one side with *Turbo* and on the other with *Cerithium* and *Purpura*, Fischer places *Purpurina* among the Littorinidæ, but its real family relationship is by no means clear. In the Jurassics of this country *Purpurina* first makes its appearance in the Marlstone (Middle Lias), culminates in the Inferior Oolite, is rare in the Great Oolite, and dies out

* I possess a specimen supplied by Sowerby and Fulton, marked "*Paramelania coronata*," Bourguignat; which greatly resembles the figures of *Nassopsis nassa*.

in the Callovian of Yorkshire. It is also represented in the Callovian of Montreuil Bellay, where a gasteropod fauna, greatly resembling that of the Inferior Oolite of the Anglo-Norman basin, is found to occur.

8. *Bythoceras*, *Moore*.

See pp. 238 and 242. There are two species figured, but, so far as I know, no special comparison with Jurassic forms is invited.

9. *Tanganyicia*, *Cross*.

See p. 246, *T. rufofilosa*. In this case also, no special comparison with Jurassic forms is instituted, but its general resemblance to *Natica* is pointed out. The fine spiral coloured lines are characteristic of this very pretty little shell, which though naticoid in its outline is certainly different as regards shell-substance to the regulation *Natica*. It is said to be a littoral form and occurs in abundance.

10. *Spekia zonata*, *Cross or Smith*, *with the Jurassic genus*, *Neridomus M. and L.*

See pp. 256 and 351. On p. 257, Moore remarks on its *naticoid* appearance, and considers it so "completely similar to that of numerous fossil naticoid forms that, had it appeared fossilized instead of having been found living in a great fresh-water lake, there is not the slightest doubt that it would have been placed in one of the numerous fossil genera which are supposed to group themselves about the living Naticas." Yet on p. 349 (the figures are on p. 351) he says: "Again we find that the shells of the Tanganyika genus, *Spekia*, are practically indistinguishable from the fossil remains of the marine Jurassic genus, *Neridomus*."

In this latter conclusion he is partly correct, for there is no doubt that the affinities of *Spekia* are with the Nerites rather than with the Naticas. *Spekia* is *neritoid*, not *naticoid*, but I fail to trace any especial resemblance to *Neridomus*. If the reader turns to the illustrations on p. 351, he will perceive that the two representations of *Spekia* are back views, whereas the two intended to represent *Neridomus* are front views, nor does the author assist the comparison in the text. But if we take a typical Jurassic *Neridomus* such as *N. Hemispherica* from the Great Oolite of Minchinhampton, which may be regarded as the type on which *Neridomus* was founded, we at once find that the columellar region is convex and the shell imperforate, whereas in *Spekia zonata* the columellar region is extremely concave, and in some specimens a peculiar umbilical slit is noticeable. Hence, beyond the fact that both *Spekia* and *Neridomus* belong to the Neritidæ there is very little resemblance so far as the anterior aspect is concerned. It may be remarked, in conclusion, that *Spekia zonata* is related to *Veritina* rather than to *Nerita*. There is nothing naticoid about it, and moreover its thick epidermis and general aspect are highly suggestive of fresh-water conditions, although its shape may be somewhat unusual.

Of the remaining genera of Gasteropods enumerated, none are especially correlated with Jurassic forms, although they are regarded as belonging to the halolimnic group. *Syrnolopsis* is a genus of small elongate shells represented by two species, and there is stated to be an almost exact conchological identity (p. 219) between these shells and the marine genus *Syrnola*. It is not necessary here to comment on all the remaining halolimnic genera, consisting mostly of small forms, but I would point out certain conclusions with reference to some of them, *e.g.*, *Reymondia*, Smith. There are several species, mostly small, but *R. horei*, Smith, is the most conspicuous form, and may be taken as the type. I mention the circumstance because of the very considerable conchological resemblance between this very smooth shell and some of the Jurassic species such as "*Phasianella*" *elegans*, M. and L., and other sub-elongate forms. This identification seems to have escaped Mr. Moore. I don't attach any importance to it, since neither *Reymondia horei* nor "*Phasianella*" *elegans* have any special features of ornamentation like *Amberleya* and *Purpurina*. There is also another case of mock resemblance, where *Horea ponsonbyi*, Smith, presumably a Prosobranch, bears a strong likeness to some of the striated *Actæoninæ* of Jurassic age; whilst the remarkably straight columellar lip of *Horea* reminds one of *Orthostoma*, which is, I believe, a synonym of D'Orbigny's genus, *Actæonina*.

Not the least interesting of the Tanganyika molluscs is the handsome viviparoid shell, *Neothauma*, whose varieties are figured on p. 261. This of course is a thoroughly fresh-water genus, and has no connection with the halolimnic fauna beyond sharing the hospitality of the same lake. One of the most remarkable characteristics of *Neothauma* is the extraordinary difference, judging from the figures, between shells from the south of the lake, and those from the middle and the north. If the internal structure is the same in all three, we have again an instance of the difficulty of recognizing an animal by means of its shell even in living creatures. Here again is a singular instance of mock resemblance to a Jurassic species, since the strap-like or bicarinate variety of *Neothauma* would also do for the figure of *Cloughtonia cincta*, Phillips, a well known fossil of the Inferior Oolite of Yorkshire and the East Midlands.

Postscript. This appendix was written before I had the advantage of hearing Mr. Edgar Smith's presidential address to the Malacological Society, delivered in February last. It was highly satisfactory to find that the chief conchological authority in this country had arrived at pretty much the same conclusions as myself, with regard to the presumed connection between the halolimnic gasteropods of Tanganyika and certain shells of the Inferior Oolite.

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